THE SCIENCE OF HEALTH AND DISEASE

Courtesy Eastman Kodak Company

PLATE I. X-RAY PICTURE (RADIOGRAPH) OF THE SKULL.

X-rays, discovered by Roentgen in 1895, affect photographic films as do the rays of sunlight. Unlike sunlight, X-rays are capable of passing through flesh; hence shadow pictures can be taken with them. Dense structures such as bones partially stop the rays and so cast shadows seen as gray when the film is developed. Metallic substances are even more opaque; the fillings in the teeth cast a white shadow.

Attention is called to the vertebrae (see page 426)—the button shown was on the clothing worn when the picture was taken; the frontal sinus and antrum (see page 225); the mastoid bone (see page 379); and the small depression in the floor of the skull, directly over the joint of the jaw, which holds the pituitary gland (see page 409).

THE SCIENCE OF HEALTH AND DISEASE

A Textbook of Physiology and Hygiene

REVISED EDITION

By

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With an Introduction by
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ILLUSTRATED

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This book is complete and unabridged in contents, and is manufactured in strict conformity with Government regulations for saving paper.

TO

PROFESSOR YANDELL HENDERSON

IN CORDIAL APPRECIATION

OF OUR LONG ASSOCIATION

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INTRODUCTION

By Yandell Henderson

MEDICINE, TOGETHER WITH RELIGION, ORIGINATED IN MAGIC. UNTIL QUITE recent times it retained an occult character, which gradually became merely secret without supernaturalism, and finally only slightly secretive. I can remember, only thirty years ago, asking a doctor who had given me a prescription for a cold, "What is it?" He replied that it was "Something to cure the cold." Even more recently I remarked of a certain disorder, from which an acquaintance was suffering, "Medicine can do little or nothing for it"; and this brought the reply, "True, but the doctor takes the responsibility!" Ignorance on the part of the layman was the psychological foundation on which the physician built that awe of his mysterious power which was supposed to be—and was in a sense—as important as the ingredients of his pills and elixirs.

Such an attitude is a thing of the past. It is immensely to the credit of the medical profession that it has thrown open all the portals of its knowledge. Anyone may enter and possess himself of all; nothing is withheld, or made in the least degree more difficult or mysterious than it is by nature. The physician and the surgeon pretend to no esoteric knowledge. They deserve and receive the highest respect, and render an inestimable service, not because they can describe a certain bone or bacterium better than a layman, but because they have acquired the practiced eye, the skillful hand, and the mind judicious in weighing a special type of evidence.

And yet much obscurantism persists. It persists particularly in what would be thought the least likely place—in education and particularly in medical education. It seems that the medical profession, and particularly the professors in medical schools and those instructors who go over to the college to give a course for undergraduates, are overwhelmed by the immensity of the details of medical knowledge. They cannot believe that the broad, general, major matters in the science of modern medicine are of no greater volume, and of rather less difficulty, than those of such subjects as physics or economics. It is a subject of which any undergraduate student in college, or even in the high school, should be able to acquire the elements in a single course of three exercises a week for a year. The hard-driven medical student spends

four years in arduous details. Even when he receives his degree and goes on to the hospital, or into practice, he still "cannot see the forest for the trees."

This book aims to "show first the forest" to anyone who wishes to see it. Every educated man should see it. For his own physical welfare and that of his family; for an understanding of what man is and his place in nature; for correct political opinions on the most important of all public questions, those of public health; for the profitable management of the employees whose working bodies, even more than factory buildings and machinery, produce the wealth of the industrialist; for all these reasons a broad understanding of the meaning of modern medical science, that is, applied physiology, is as important as any element in education.

This book is intended particularly for three classes of readers:

First, it is for employers and engineers in charge of labor. It aims to give them a practical understanding of what the human body is, how it may best, most productively and profitably be utilized as a part of industrial machinery, and how by conserving it the charge on industry for worn-out and injured human bodies may be reduced to a minimum.

Second, it is a textbook for college students. It aims to afford them a general acquaintance with medical science, physiology in its broadest senses and applications, of a grade suitable for undergraduates. In the form of lectures and a syllabus for student reading the material here presented has, in fact, been used for some years past for undergraduate students in a large elective course in Yale University.

Third, this book is a broad survey of the whole field of modern medicine such as should be given in the initial course in the medical school. Years ago when the sciences of anatomy, physiology, and pathology were still newcomers in the medical curriculum, it was considered necessary to keep the first few terms wholly clear of interest in the applications of these sciences to clinical matters. But now the medical sciences will rather gain if the student is first given a broad survey, so as to see to what practical uses the theoretical subjects will ultimately lead him.

It was never so true as now that "the proper study of mankind is man." Modern science has destroyed that essentially theological universe in which Creation culminated in the human body, and in which that body was regarded merely as a temporary habitation for a non-corporeal soul. Even if the Fundamentalists should succeed in binding education to their dogmas, and even if the Anti-vivisectionists, Anti-

vaccinationists, and others of their kind should have their way, the result would not be a return to the historically beautiful, but in reality disease and superstition ridden, "age of faith." It would instead be the end of civilization.

Nevertheless, the minds of educated men today stand shivering in a universe of inconceivable immensity. Something within us cries out for the basis of a new philosophy by which mankind can live. We must have courage to face the truth, for if it is not based on truth no philosophy of man's mission and fate will meet the test of practical application. To such a philosophy all the sciences must contribute, but none of them contributes a more important truth than physiology. It tells us first what man is: Man is an animal. Until quite recent times he was as helpless before nature and its diseases as any other animal. Now modern science is making him master of his own fate. But it does so only on condition that he obey the ancient commandment of the Delphic Oracle, "Know thyself."

CHAPTER I

THE HUMAN MACHINE AND THE SOURCE OF ITS ENERGY

THE PHENOMENON KNOWN AS LIFE IS INSEPARABLY CONNECTED WITH THE expenditure of energy. When the human body ceases to move, and no longer liberates heat, it is dead.

The study of physiology, with which this book is primarily concerned, deals with the activities—the workings—of the body. All these activities, from the most elementary process of digestion to the most complex process of thought, involve expenditure of energy.

The body possesses no inherent source of energy; it derives the energy which it expends from the food which is eaten.[1] The body is an energy-transforming machine. The carbon and hydrogen, which are the combustible elements of food, are burned in the body, and the chemical energy thus liberated is transformed into energy in the form of work and heat.

Not only the human body but all forms of living matter possess in common the fundamental property of transforming energy. The activities of all living things from the most elementary to the most complex are expressions of this fundamental property.

Forms of Energy.

In physiology the term energy is used with precisely the same meaning as that given to it by the physicist, the chemist, and the engineer. Various loose connotations of the word used in common speech, as "he speaks with energy," and "he is energetic," have no place in physiology, and neither has such a meaningless expression as "nervous energy."

In the living body the liberation and transformation of energy follow exactly the laws defined in the mathematical sciences. Energy cannot be created, and it cannot be destroyed; but it can be, and constantly is, transformed from one form into another. In physics and engineering it is the practice to apply a separate unit to the measurement of each

[1] Fat stored in the body and the protein of vital tissues may for a time be used as a source of energy when the intake of food is inadequate to supply the body's needs; the fat and protein thus used are derived from the food eaten at some previous time.

form of energy; the calorie or the British Thermal Unit for heat, the watt for electricity, and the foot pound or the kilogram meter for mechanical work.[1] But it is also possible to apply a single unit to all forms of energy. This is the practice in physiology. The unit employed is the calorie. A calorie is defined as the amount of energy, as heat, required to raise 1 cubic centimeter of water (1 gram) through 1° centigrade and is expressed by the symbol c. The kilocalorie is 1000 of these gram-calories and is expressed by the symbol C. The large calorie—kilocalorie—is the one used in physiology unless special reference is made to the contrary.

The available chemical energy contained in food is expressed in calories; the number of calories represents the amount of energy which a given weight of food will provide the body for liberation in the form of heat or movement. Table VI, page 99, gives the energy content of some of the more common foods.

Elementary Structure.

The body of man is not homogeneous, is not made up of clotted gelatinous humors, but is composed of individual units microscopic in size. Each of these units is a living entity; each possesses the ability to transform energy; each requires a constant supply of food for this transformation; and each, if taken from the body and kept under suitable conditions, can continue to exist and perform independently the fundamental activities of life. The units of the human body are called cells.

There are many living organisms, both plant and animal, which consist of a single microscopic cell—the common yeast plant is such a one. A cake of yeast consists of a mass of single cells, each one a living organism, with virtually the same fundamental vital properties as the human body. A yeast cell placed in a solution of sugar and water absorbs the sugar, burns it within the cell, liberates carbon dioxide, and generates heat; similar organisms may also move.

The body of a man and a cake of yeast have ultimately the same elementary structure; each is an aggregation of cells. Although the cells of which they are composed have the same fundamental properties, the differences in the character and scope of the activities of a man

[1] 1 kilocalorie = 3087 foot pounds.
1 " = 3.97 British Thermal Units, B.T.U.
1 " per minute = 70.1 watts.
1 " " " = 0.094 horsepower.
A man of average size sitting at rest expends 80 to 100 calories per hour (see page 96).

and a cake of yeast are tremendous. These differences are due to the specialization and cooperation of the cells which compose the various parts of the human body.

A unicellular organism, on the one hand, is like a man working entirely for himself with no relation to other men; the body, on the other hand, is like an enormously complex society of men. An isolated man must make his own clothes, hunt his own meat, raise his own vegetables, carry his own water and hew his own wood—in short, perform all the activities necessary for his maintenance. Because of this diversity of activities his effectiveness in any one line is limited. In a society of men, on the contrary, there is a specialization of workers and a division of labor toward common ends. Similarly, in the human body there are various types of cells; each variety performs a particular function for the body as a whole and hence relieves other cells of this responsibility so that they can devote themselves intensively to specialized functions of their own.

Differentiation of Cellular Structure and Specialized Properties of the Tissues.

Tissues are the different kinds of flesh—materials of which the body is constructed. Each tissue is a group of cells differentiated to a particular type of structure which fits them to perform a specialized function. There are only a few basic tissues, although each may show variations; taken in combination they compose all the organs of the body. They are muscle, bone and fat, and the epithelial, glandular, nervous and connective tissues.

1. *Muscle* is made up of elongated spindle-shaped cells, each of which possesses in high degree the power to contract along its long axis into a shorter and broader spindle. The physical work of the body is done by the muscular tissue.

2. *Bone* (which is often classed as a special form of connective tissue) is a very dense, hard tissue, for its cells deposit lime salts. The bones are rigid; they form the framework of the body, the skeleton, and are the levers through which the power of the muscles is applied.

3. *Fat* is made up of cells which have the capacity of storing, within their substance, droplets of oil—fat. This tissue thus affords a store of fuel which is released and burned when the food eaten is insufficient to supply the energy needs of the body. When the food supply is greater than that needed, fat is deposited in the cells of the fatty tissues which thus increase in bulk.

4. *Epithelial tissue* forms the covering for the surface of the body. The skin is composed of epithelial tissue, the outer surface of which is made more resistant to injury by a coating of cells which have been transformed into keratin, the material which also makes up hair, finger and toe nails and horn.

5. *Glandular tissue* is specialized to perform complex chemical transformations such as those by which milk is produced by a cow fed on grain or grass. Glands secrete such fluids as saliva, the digestive juices, sweat and urine; others form complex chemical substances needed for the regulation of the functions of the body and discharge their secretions neither into the digestive tract nor outside of the body, but instead into the blood. They are the glands of internal secretion.

6. *Nervous tissue* is composed of nerve cells from which slender fibers extend to interlace with extensions from other nerve cells or make contact with cells of other kinds of tissue; it serves as a kind of switchboard to and from which nerve fibers are stretched like wires to connect with and control all parts of the body.

7. *Connective tissue* consists of minute but strong fibers which permeate and bind together the various structures of the body and act as a supporting frame for all other tissues. This tissue is the material of which the tendons, cartilage and ligaments are composed.

Organs of the Body.

It is of these tissues that the organs of the body are composed. Each organ may be thought of as a relatively independent machine performing some special service for the body. In this respect they may be compared to the carburetor of an automobile, the governor of a steam engine, or the water pump of a boiler. Just as these mechanical devices are made up of different metals, so the organs are composed of various tissues.

The heart, liver and intestines are some of the organs of the body. The heart is a bulb of several chambers; it is composed mainly of muscular tissue which contracts and squeezes out blood which fills the chambers. It serves as a pump to circulate the blood through the blood vessels. The liver is composed of gland cells supported in a framework of connective tissue. This organ secretes a fluid used in the digestion of food, and is a storage depot for sugar. The intestines are in the form of a tube of which the walls are muscular tissue lined with epithelial tissue and covered with connective tissue.

The organs just mentioned are regulated unconsciously—that is,

automatically or involuntarily. The construction of one of the parts of the body which is under conscious control may be illustrated by the arm and hand. In the center of the arm a number of bones are placed end to end and held together by ligaments of connective tissue. The bearing surfaces or joints are lined with connective tissue in a form called cartilage. About the bones are bundles of muscular tissue. Each muscle cell is held in a sac of connective tissue. Minute cords of connective tissue are fastened to bones on opposite sides of one or more joints. Contraction of the muscle pulls upon the tendons and through them moves the bones, as levers, about the joints which act as fulcrums. Over the muscle is an insulating layer of fat, and upon this a layer of connective tissue which in turn bears the skin. Glands which secrete sweat, and others which secrete oil, have openings through the skin and pour their secretions upon the surface. Blood vessels, which are tubes of connective and muscular tissue lined with a tissue somewhat resembling epithelium, ramify through the tissues of the arm and supply them with nutriment and carry away the end products of their chemical reactions. Nerves run to the cells of the tissues and carry to them impulses which control their action. Other nerves carry impulses, some of which we feel as sensations, from the skin, muscles and joints, to the spinal cord and brain.

Systems of the Body.

A group of organs working together to effect some particular function in the body is called a system. The alimentary system, circulatory system, and nervous system are examples of this functional grouping of organs.

The alimentary system, consisting of the mouth, stomach, intestines, and such glands as the liver and pancreas, is concerned with the preparation of food for absorption into the blood.

The circulatory system, consisting of the heart, the blood vessels and the blood, has as its function the transportation of material from one part of the body to another.

The nervous system, consisting of the brain and spinal cord, the nerves and the sense organs, serves to regulate and direct the activities of the other organs so that all parts work together and the body acts in relation to its environment.

The respiratory system, consisting of the lungs and respiratory passages, brings oxygen to the blood and also affords a channel of egress

for the carbon dioxide which arises from the combustion of fuel within the tissues.

The urinary system, consisting of the kidneys, bladder and urinary passage, has an excretory function complementary to that of the respiratory system. It affords an egress for solid waste materials.

The muscular system furnishes the power for all movements of the body. The movements exerted through the bones and joints are the most apparent but not the most important. Such movements serve to carry the body to its food or away from its enemies. There are in addition the movements by which the internal activities of the body are effected, such as by those of the heart and blood vessels.

The reproductive system furnishes the means whereby the species is perpetuated through the formation of new organisms.

Food.

Food not only supplies the fuel which provides the energy to operate the human machine, but it also furnishes the elements needed to replace the wear and tear of the tissues. Bread, butter, milk, meat and vegetables bear the same relation to the body that coal does to a steam engine, or petroleum to an internal-combustion engine; but, in addition, they serve as the materials out of which the body grows, and the engine itself is repaired.

As scientifically defined, the term food or, as we shall use it here, the "foodstuffs" composing food, has a broader meaning than merely that of fuel for energy. The foodstuffs include all substances which, when taken into the body, are used in any of its functions. This definition embraces a large number of materials which are indispensable to the body, although no energy is derived from them. Thus vitamins and a variety of mineral substances are classed as foodstuffs. There is no term dealing with machinery which is exactly comparable to the word foodstuff. Such a term would be some generic name covering, in addition to fuel, such items as lubricating oil, iron and copper for replacing burned-out parts, and in general a supply of the materials of which the engine itself is composed.

One basis for estimating the extent of the body's reserve supply of any particular foodstuff is the length of time that the body can continue to live after being deprived of it. Men have fasted for periods of forty to sixty days. The result is a large loss of weight, for when no fuel is furnished, the body burns its own fat which has been stored away against just such a lean period. Deprivation of water is more

serious than deprivation of food. The body is two-thirds water, but it has no large excess and the outgo is continuous. Less than a week of complete deprivation of water is fatal. Oxygen is the substance most constantly in need of replenishment. When the supply of air is shut off, as, for example, by drowning, there is so small a store of oxygen in the body that death results within ten minutes.

Fuel Foods.

The human machine derives its energy from the combustion of carbon and hydrogen, but neither of these elements in the free state can serve as a food, for the body is not equipped to burn them. Neither can they be utilized in all of their combined and combustible forms. Coal and petroleum are excellent fuels, but they cannot be utilized as such in the body, for they pass through the digestive tract undigested and unabsorbed. To be available for the vital activities of the body, a fuel food must first be converted by digestion into a soluble form which can be absorbed from the alimentary canal into the blood. Digestion in man, as will be seen in a later section, is capable of rendering soluble and absorbable only a limited class of combustible substances: the carbohydrates, fats, and proteins. These are the fuel foods.

Carbohydrates.

Starches and sugars constitute the class of carbohydrates. For the most part they originate in plants where they are formed from carbon dioxide and water by the process of photosynthesis. Carbohydrates furnish the bulk of our diet, for they are the main foodstuff in potatoes and other vegetables, and in the cereals and cereal products such as wheat flour, oatmeal and cornmeal. Few articles of diet, except honey and such highly purified ones as cornstarch and cane or beet sugar, consist wholly of carbohydrate; most contain proteins, fats, water, fiber and minerals. The table given on page 99 shows the proportion of carbohydrate present in some of the more common foods.

As their name implies, the carbohydrates are composed of the three elements, carbon, oxygen and hydrogen. The carbon alone is combustible, however, for the hydrogen and oxygen are present in the proportion which forms water; that is, every carbohydrate contains exactly twice as much hydrogen as oxygen. The chemical formula for cane sugar is $C_{12}H_{22}O_{11}$—12 carbon atoms attached to 11 molecules of water $11H_2O$.

The reaction by which the chemical energy of fuel foods is liberated in the body is an oxidation; oxygen, derived from the air breathed, and brought by the blood to the tissues, combines with—oxidizes—the food. This oxidation takes place within the cells. Hydrogen is burned to water and carbon to carbon dioxide, CO_2. In the case of carbohydrates the hydrogen is already in combustion with oxygen, and only the carbon can be burned.

Although all carbohydrates have the same general relation between the elements that compose them, some are of more complex structure than others. The simple sugars are glucose (grape sugar), fructose (fruit sugar) and galactose. When eaten, these carbohydrates require no digestion; they are dissolved in the fluids in the alimentary tract and absorbed directly into the blood. Milk sugar (lactose), cane sugar (sucrose), and malt sugar (maltose), are more complex; each consists of a chemical combination of two simple sugars. Lactose is made up of glucose and galactose; sucrose, of glucose and fructose; and maltose, of two molecules of glucose. During digestion these carbohydrates are acted upon by digestive ferments and broken down into their component simple sugars and these in turn are absorbed. Starch is still more complex in its structure, consisting of numerous molecules of glucose linked together; it is broken down by digestion into its component parts and the glucose thus freed is absorbed into the blood. There are certain carbohydrates which, although they consist chemically of combinations of simple sugars, cannot be rendered soluble by digestion. Of these, cellulose, which forms wood, the fiber of plant stems, and the envelope about the cells of leaves, is the most important. The cow and the horse can utilize some cellulose,[1] but man cannot. In his digestive tract it provides "roughage," bulk, to stimulate the normal action of the intestines but it furnishes no nourishment.

A gram of sugar, or any common carbohydrate, burned in a calorimeter liberates approximately 4.1 kilocalories of heat. When burned in the body it liberates the same amount of energy in the forms of work and heat. This value of 4.1 calories per gram is known as the calorific value of carbohydrates; it is used in all dietary calculations.

Fats.

Fats are obtained from both animal and vegetable sources. Lard, suet and butter are typical animal fats, and olive oil, cocoa butter and

[1] The digestion is assisted by bacterial action in the alimentary tract.

cottonseed oil are representative of the vegetable types. Reference to the table on page 99 shows that foods from nearly all sources contain some fat but that the amount varies widely; thus apples contain less than 0.5 of one per cent; at the other extreme, bacon contains some 65 per cent and butter 85 per cent.

Judged by their appearance and physical properties, there are nearly as many varieties of fats as there are sources from which they come. Regardless of their apparent differences, fats are essentially alike in chemical composition. They are all combinations of fatty acids with glycerin. Glycerin is an oily substance, but soluble in water, a triatomic alcohol which has the chemical formula $C_3H_8O_3$. It is employed in the preparation of high explosives such as nitroglycerin, is used in anti-freeze mixtures for automobiles, and is a constituent of many hand lotions and cough drops. The main fatty acids in the fats of foods are palmitic, stearic, and oleic. When glycerin is combined with palmitic acid the fat palmitin is formed, with stearic acid the fat stearin, and with oleic acid the fat olein.

When a fatty acid and glycerin combine to form fat, three radicals of the fatty acid unite with one molecule of glycerin; three molecules of water are separated off. Thus in the formation of the fat palmitin:

$$\underset{\text{Glycerin}}{C_3H_8O_3} + \underset{\text{Palmitic acid}}{3(C_{16}H_{32}O_2)} = \underset{\text{Water}}{3\ H_2O} + \underset{\text{Palmitin}}{C_{51}H_{98}O_6}$$

During the digestion of fat this reaction is reversed; three molecules of water are added to the fat and the combination is then split into its component parts: one molecule of glycerin and three of fatty acid. These two products are absorbed into the wall of the intestine, recombined to form fat, and passed into the blood. The soapmaker carries out essentially the same procedure as that which occurs in the digestion of fat. He separates the glycerin and the acid of the fat; but he removes the former and combines the acid with sodium or potassium. Soap is different from fat in being the sodium or potassium salt of palmitic, stearic, or oleic acid instead of the glycerin salt. Although the body could derive energy from soap, the corrosive action of the soda or potash liberated during digestion prohibits its use as an article of diet.

The melting point of palmitin and stearin is above the temperature of the body, while olein is a liquid at ordinary temperatures. The fats of food are mixtures of these three fats and the melting points are dependent mainly upon the proportion of olein which is in the mix-

ture. All fats encountered in ordinary foods melt below body temperature; a fat that has a higher melting point remains as a solid in the digestive tract and is attacked with difficulty by the digestive fluids.

From observation of chilled butcher's meat we are accustomed to think of animal fat as a solid material, but in reality it is melted at the temperature of the living body and exists there in the fluid state in minute globules within the cells. If the fat of the body were congealed, the flesh would become stiff; and if it were not within the cells, the liquid fat would flow about among the tissues.

A man whose diet contains olive oil, or lard, or butter, or, indeed, any form of fat in excess of his immediate energy needs, stores the excess as fat—human fat. Each animal, including man, tends to deposit a certain combination of palmitin, stearin and olein which is characteristic of the fat of the particular animal. But when any particular fat is eaten in large amounts the requisite proportion may be lacking; the fat deposited then tends to resemble the fat eaten. Under ordinary circumstances human fat contains 15 to 20 per cent of palmitin, 6 per cent of stearin and 65 to 85 per cent of olein.

In contrast to the fats used for fuel, there are in the body other types of oily substances which are not utilized in this way but are essential ingredients in the cells. Some of these "fats" contain nitrogen and phosphorus as well as the fatty acids, and others contain a substance known as cholesterol.

When fat is burned as fuel in the tissues both carbon and hydrogen are oxidized, for unlike that of carbohydrate, the hydrogen of fat is not already fully combined with oxygen. Fat has the greatest heat content of any of the fuel foods. On combustion one gram of fat liberates approximately 9 kilocalories of energy.

Proteins.

Proteins bear a more intimate relation to the body than do other fuel foods. They are an essential vital constituent of the body cells. The service of proteins as fuel foods is subordinate to their important functions in growth and replacement of tissues. A supply of proteins in the diet is necessary for the maintenance of the body, but an excess is an expensive and physiologically uneconomical form of fuel, for the proteins, unlike carbohydrate and fat, are incompletely burned when used for the liberation of energy.

Although, as seen from Table VI, page 99, nearly all foods contain

some protein, the amount is widely variable. Most vegetables, with the exception of the legumes like peas and beans, contain little protein; the cereal products, from 8 to 14 per cent; the meats, chiefly muscle tissue, from 6 to 20 per cent; and milk, about 3.5 per cent.

Proteins contain nitrogen and sulphur and sometimes phosphorus, in addition to the carbon and hydrogen of which carbohydrates and fats are composed. The percentage of the elements in proteins varies within narrow limits; the average composition is as follows:

Carbon	52	per	cent
Hydrogen	7	"	"
Oxygen	23	"	"
Nitrogen	16	"	"
Sulphur	2	"	"

The content of nitrogen—16 per cent—is of special importance in physiological studies; the nitrogen cannot be oxidized in the body, and during the combustion of protein it is separated, carrying with it some of the carbon and hydrogen in the form of urea. The urea is eliminated through the urine. This excretion of nitrogen thus affords a means for determining the rate of combustion of protein in the body (see page 79).

The chemical composition of proteins is exceedingly complex. They are built up of groups of interconnected amino acids. An amino acid is an organic substance which has a nucleus of carbon, hydrogen and other elements to which are attached two radicals which give it its peculiarities: the amino group (NH_2) and the carboxyl group ($COOH$). The amino group is alkaline in reaction; it is capable of combining with acids. The carboxyl group is acid; it is capable of combining with alkalies. In the formation of a protein the carboxyl group of one amino acid is linked to the amino group of the next. Several amino acids are thus joined into long chains; the character of the protein thus formed depends upon the number, the varieties, and the arrangement of the amino acids present.

The structure of a protein may be compared to a mosaic pattern in which stones of different colors and shapes represent the different amino acids. The same stones could be arranged in a great variety of patterns; each pattern would correspond to a separate and distinct protein. The introduction of an additional colored stone into the pattern would greatly increase the number of the possible combinations. The differences between the proteins in the protoplasm of the cells of the horse, man, cow, or other animals, are due to the pattern in which

the amino acids are arranged and, to a much less extent, to the varying number of the different amino acids in the protein molecules. Thus it is possible to derive from the flesh of an animal used for food all of the amino acids necessary to form human flesh; beefsteak can be converted—in the body—into human protoplasm. In plant foods the pattern in which the amino acids are arranged may differ from that of animal tissue, but, what is far more important from a dietary aspect, certain of the amino acids which go to form the flesh of animals may be deficient in amount or absent. Consequently vegetable protein is not always a satisfactory dietary substitute for meat protein. (See page 81.)

The digestion of proteins consists in the disintegration of the molecules into their component amino acids. These are then absorbed into the blood. From the blood the amino acids are removed by the tissues as needed, rearranged and linked together into new proteins having the characteristics of those of the protoplasm of man. If the protein eaten is deficient in one or more of the amino acids necessary to the pattern typical of the proteins in human flesh, it cannot be reassembled in the form of human protein. Unless the diet is altered, the maintenance of tissue repair and growth suffers.

Proteins when burned outside of the body give rise to more heat than when burned inside the body. In the vital combustion the carbon and hydrogen which split off to carry away the nitrogen as urea are unoxidized. The physiological heat value of protein is approximately the same as that of an equal quantity of carbohydrates.

CHAPTER II

DIGESTION AND ITS DERANGEMENTS

UNICELLULAR ORGANISMS REFERRED TO IN THE PREVIOUS CHAPTER OBTAIN their food by absorption through the surfaces of their bodies; to live they must be immersed in food. The same is true of the cells which constitute the more highly organized human body. Every cell in the body must have, in the medium about it at all times, the materials from which it effects its energy transformations. The cells of the tissues of the human body live in the same relation to the blood, lymph, and tissue fluid that unicellular organisms do to the water of the sea, or lake, or pond in which they live immersed.

The fuel foods, as they exist in the ordinary diet, are of complex form which cannot be utilized directly by the cells of the body. By the process of digestion these foods are reduced to the simple and soluble state necessary for their absorption into the body and for their utilization by the cells. The necessary alterations are accomplished during the passage of the food through the digestive tract. This tract is a long convoluted tube extending from the mouth to the anus. There are no open communications from it into the substance of the body. The food is acted upon by the fluids secreted by the cells of the digestive tract; it is rendered soluble. Dissolved in the fluids, it diffuses through the walls of the tube into the blood. The circulation of the blood carries the dissolved and utilizable food to all the cells of the body. Material taken into the digestive tract that cannot be rendered soluble by the digestive fluids is passed through the tube and ejected from the body as fecal matter.

Material which lies within the digestive tract is, strictly speaking, outside the body. The body may be considered as a double-walled tube, the outer surface covered by the skin and the inner surface by the absorbent membrane of the gut. The inner and outer surfaces meet at the mouth and anus, and the body proper fills the space between. The indigestible material, which passes throughout the length of the tube unabsorbed, is not waste material of the body; it is detritus that has never been used by the body.

Digestion as a whole resembles the general procedure employed in the chemical industry for extracting substances from raw materials. The movement within the digestive tract is analogous to that of a conveyor system such as is used in factories to transport material from place to place in the course of its manufacture. The crude materials

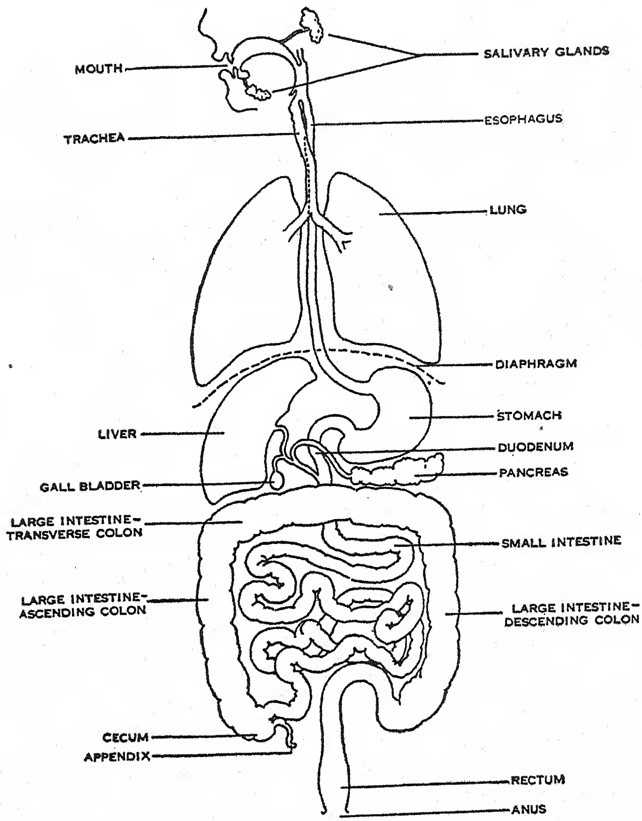


Figure 1. Schema of Alimentary Tract.

enter the hopper at the top of the conveyor and are subjected to mechanical division by the jaws and teeth. The division greatly increases the surface of the material and hence expedites the chemical action of the digestive fluids. The finely divided material is conveyed to the stomach, a reservoir, where it is treated chemically until it is reduced to a gruel, after which it is passed along gradually into the small intestine, a narrow tube some thirty feet long, where it receives

further chemical treatment and the dissolved material is filtered off into the blood. Finally the wet indigestible residue is collected in the large intestine, another reservoir, where the water is extracted and absorbed into the body for further use and the waste is concentrated as feces to be discharged by defecation.

From this general view of the process of digestion we turn now to a detailed consideration of the various steps involved.

Chemical Digestion.

The division of the food by the teeth is the only mechanical comminution exerted during digestion; the remainder of the process is accomplished by chemical action. The chemical agents that digest food are known as ferments or enzymes. Enzymes are substances, presumably of protein nature, which, when present in small amounts, are capable of inducing specific chemical changes without involving any appreciable expenditure of energy, and without themselves undergoing alteration. They behave as catalytic agents and expedite chemical reactions. The action of each enzyme is specific; thus the one present in saliva, known as *ptyalin*, breaks down starch into simple sugars; the digestive juices of the stomach contain *rennin*, which coagulates milk into curds, and *pepsin*, which partially digests protein; the fluids in the small intestine contain *lipase*, an enzyme which breaks down fat into glycerin and fatty acids, *amylase*, which completes the digestion of any carbohydrate which has escaped the action of the ptyalin of the saliva, and *trypsin*, which completes the digestion of proteins. These enzymes are formed in the glands which produce the digestive fluids. These same glands also release the necessary amount of acid or alkali to provide the proper medium for the operation of the enzyme; the saliva is nearly neutral, the secretion of the stomach is acid, and that of the intestines alkaline.

In addition to the digestive fluids the walls of the alimentary tract secrete mucus, for they are lined with mucous membrane. This tissue, which also forms the lining of the respiratory passages, contains cells which continually form a clear, colorless, and somewhat viscous fluid, mucus, which coats the surface of the membrane. In the nose infection of the mucous membrane, as in head colds, results in an increased flow of mucus which becomes mixed with pus to give the familiar yellow catarrhal discharge; similar catarrhal conditions may also occur in the intestinal tract.

Cooking as an Aid to Digestion.

Man is omnivorous, that is, he eats all types of food, but his teeth and the movements of his jaws are less effective on each variety of food than are those of animals which are either exclusively carnivorous or herbivorous. Raw meat and cereals, uncooked and unground, are incompletely utilized by man; but if cooked so that they are softened, they can be readily masticated.

Digestion commences in the kitchen. Materials which, if raw, would be attacked with difficulty are rendered easily digestible by cooking; the boiling or roasting of meats softens and swells the fibers and thus makes them more permeable to the digestive fluids. An indigestible membrane of cellulose surrounds the starch grains of cereals and vegetables; this capsule is ruptured by cooking and the liberated starch is changed to a soluble form.

Digestion in the Mouth.

Digestion in the mouth consists in dividing the food mechanically with the teeth and mixing it with saliva. In mastication, or chewing, the food is pushed between the teeth by the tongue and cheeks and ground up by the lower jaw acting against the upper under the force of powerful muscles. The movements involved in chewing are intermittent. During the time when the lower or movable jaw is relaxed, the tongue and cheeks cooperate in bringing new or incompletely masticated portions of food into position to be crushed during the period of closing. Normally, mastication is continued until the food mass is reduced to a finely divided moist state which is suitable for swallowing.

The mastication of food is an important step in digestion. Improper mastication leaves the food in masses of a size not readily accessible to the digestive fluids. This results in slower digestion and in irritation of the digestive tract. Other than mastication, the digestive processes are involuntary and when once initiated are beyond the control of the will, although affected by emotions. Mastication is subject to much neglect from the habit, either nervous or environmental, of bolting food. Much so-called "indigestion" is not due to any disorder of the stomach, but arises from the difficulty with which a normal organ acts upon material inadequately prepared.

Teeth and Gums.

It is impossible to masticate solid food properly unless the teeth and gums are healthy. An adult is normally provided with sixteen teeth in

each jaw, or rather fourteen, as the "wisdom" teeth are seldom perfect. These are the permanent teeth, so-called to differentiate them from the temporary or deciduous teeth of childhood. The four front teeth in each jaw have incisor edges suitable for biting off or gnawing the food. The three molar teeth in the back of the jaw on each side are broad and have grinding surfaces. The canine and bicuspid teeth,

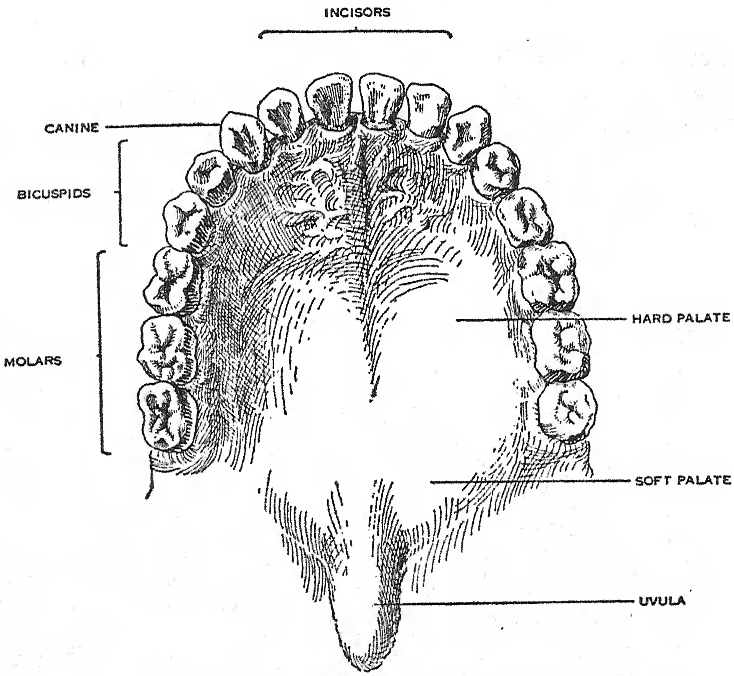


Figure 2. Upper Dental Arch and Palate.

Firmness is given to the hard palate by the plate of bone above it, shown in Figure 7. The soft palate terminates in the conical structure known as the uvula, which is shown in front view in Figure 26.

which are between the incisors and molars, are intermediary in character and function. In carnivorous animals the canines are the principal weapon of offense and are used for tearing flesh. When a man is angry he draws up his upper lip, and this snarl exposes the canine teeth, just as in the beasts which fight with their teeth.

The incisor teeth of the upper jaw are wider than those of the lower. with the result that every tooth in the lower jaw, with the exception of the incisors, is in relation with two teeth in the upper jaw; conse-

quently the teeth of the two jaws mesh together, the projections, or cusps, on the surface of the teeth of one jaw fitting into the depressions in the teeth of the other. A slight lateral movement of the jaw thus results in an effective grinding of food placed between the molar teeth. In most individuals the incisor teeth of the upper jaw are set farther forward than those of the lower. This overlapping of the incisor teeth gives a shearing action in biting off food.

Structure of a Tooth.

Each tooth consists of a crown, neck, and root or roots. The crown is the part which projects above the level of the gum, the neck is the

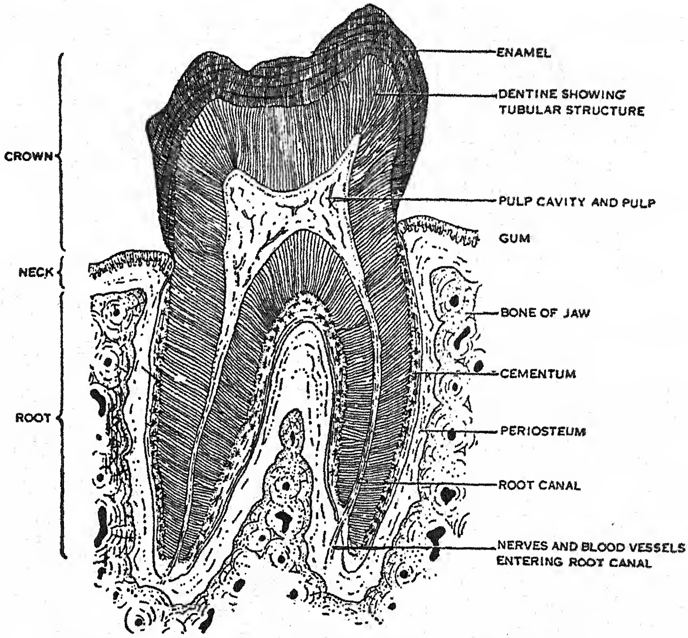


Figure 3. Longitudinal Section of Normal Tooth.

constricted portion embraced by the gum, and the root includes the remainder of the tooth which is buried in the jawbone.

A tooth is composed principally of dentine or ivory. A layer of hard enamel covers the dentine of the crown. In the center of the tooth is a small cavity which opens at the tip of the root for the entrance of blood vessels and nerves which form the pulp filling this cavity. The

surrounding dentine is channeled by a multitude of minute tubes which by their inner ends communicate with the central cavity and extend outward to the enamel. These tubules of the dentine are really extensions of the central cavity and are filled with the same pulp material. A tooth is a living structure which is permeated by soft flesh-like material.

Development of the Teeth.

A baby usually has no teeth showing through its gums at birth, but the formation of the teeth has nevertheless been going on for nearly eight months. From that early date onward the development and growth of the teeth continue until the twentieth year. Table I shows

TABLE I.—CHRONOLOGY OF TOOTH FORMATION

Name of Tooth	Time of Eruption, Months	Time Shed, Years	Time Dentine Formation Starts	Time Enamel Formation Is Complete
TEMPORARY TEETH				
Central incisors	6–8	7th	4 mo. before birth	1 month
Lateral incisors	7–9	8th	4 " " "	At birth
First molars	14–15	12th	3 " " "	6 months
Canines	17–18	10th	3 " " "	6 "
Second molars	18–24	12th	3 " " "	7 "
PERMANENT TEETH				
	Years			
First molars	6–7		1 mo. before birth	5 years
Central incisors	7–8		1st year	5–6 years
Lateral incisors	7–8		1st "	6–7 "
First bicuspids	10–11		4th "	8 "
Canines	12–13		5th "	7–8 "
Second molars	12–14		5th "	9 "
Third molars	17–18		9th "	11 "

the ages at which the formation of the dentine in the various teeth starts, and the time at which the enamel formation is completed. This table shows also the average age at which the temporary teeth (to be discussed below) erupt and are shed, and also the time of eruption of the permanent teeth. The roots of the teeth continue to grow for some time after the enamel formation is complete; thus in the case of the second molar, the last to appear before the wisdom teeth, although the enamel is completely formed by the ninth year and the tooth erupts about the twelfth year, the growth of the roots is not completed until the seventeenth or eighteenth year.

A tooth starts as a "germ," a small mass of connective tissue that forms in the jaw. Next calcium is deposited in the connective tissue

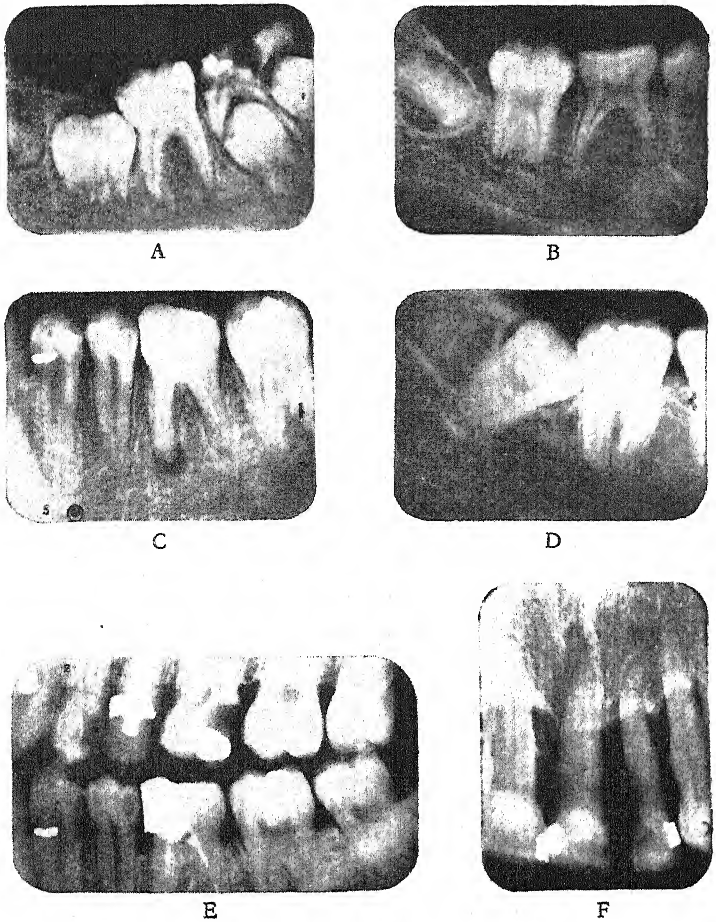
as in the formation of bone; this stage marks the beginning of dentine formation as noted for the various teeth in Table I. A layer of epithelial tissue grows about the dentine and is gradually changed into the enamel that finally covers the crown of the tooth. As the tooth grows larger it forces its way upward, finally breaking through the gum—erupting. The eruption of the teeth is accompanied by some pain and discomfort that may make a child fretful, but the belief that "cutting the teeth" may be responsible for severe illness is false. It is a fallacy responsible for the tendency to dismiss all symptoms of disease in the first two or three years of life as due to teething; severe infections in the throat and ears are for this reason sometimes overlooked.

The temporary teeth are smaller than the permanent teeth but their size is suited to the immature jaw, as it has to grow to a size large enough to hold the permanent teeth that gradually replace the temporary ones.

The permanent teeth form in the same way as the temporary teeth; as they grow outward the roots of the temporary teeth are gradually absorbed, and those teeth then become loose and are shed. Occasionally the germ of a second tooth fails to form and the tooth cannot develop. The temporary tooth at this point may then stay in place many years beyond its usual period. When a tooth fails to erupt at the expected time the presence or absence of the "germ" can be determined by X-ray examination—a point of some importance, for long-delayed eruption may be due not only to the absence of a germ but also to abnormal development in which the tooth, instead of growing outward, grows at a slant which brings it against the side of an adjacent tooth, an impaction which requires dental surgery for correction.

Abnormal Position of Teeth.

The conformation in which the teeth of the upper and lower jaws meet, the "bite," is of great importance not only for the preservation of the teeth, but for the shape and appearance of the face of which the jaws are a prominent feature. The formation and growth of both jaws in early life are in part dependent upon forces exerted by the pull of muscles during chewing. The temporary teeth exert an important guiding influence; their premature extraction upsets muscular balance and may thus result in an asymmetrical development of the jaws. Likewise a too extensive use of soft foods by limiting the activity of the muscles may similarly affect the shape of the jaws. Infection from the decay of temporary teeth may lead to infection in the perma-



Courtesy Eastman Kodak Company

Plate II.—Dental Radiographs.

(A) Two deciduous and five permanent teeth are shown. The first permanent molar has erupted and already has a filling. The second and third molars and the bicuspids have not yet erupted. Absorption is nearly complete in the roots of the first deciduous molar, which is above the first permanent bicuspid, and has started in those of the second deciduous molar. There is a large cavity in this tooth. See page 19.

(B) The middle erupted tooth is a deciduous second molar which has persisted because the second bicuspid has failed to develop. The second permanent molar is forming in its capsule.

(C) Abscess at the root of a molar. This tooth is dead and an unsuccessful attempt has been made to fill the root canals. See page 24.

(D) An impacted third molar. See page 20.

(E) A radiograph of the crowns of the teeth used to locate cavities.

(F) Destruction of the jaw bone by pyorrhea; the teeth are loose. See page 25.

nent teeth forming below them. For these reasons the first teeth deserve good dental care in spite of the fact that they are only temporary.

Dental disturbances are not the only cause of imperfect development of the jaw. Thus obstruction of the upper respiratory passage from enlarged adenoids (see Figure 7) causes "mouth-breathing"; the disuse of the nasal passage may be followed by underdevelopment of the floor of the nose, and the floor of the nose is the roof of the mouth. A narrow upper jaw and a narrow face may result if the obstruction to breathing is allowed to persist. Asymmetry of the jaws,

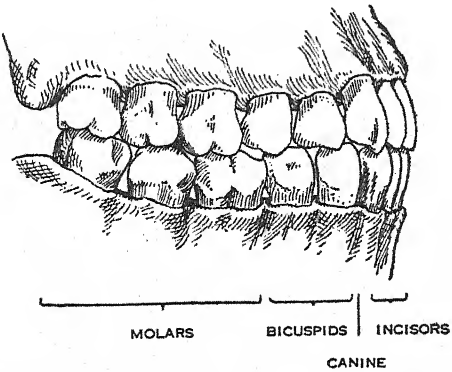


Figure 4. Teeth of Upper and Lower Jaws in Apposition.

and also prominence or recession of either jaw, may result from disturbances in the secretion of those glands of internal secretion which influence bone development, especially the pituitary gland; often the malformation shows an hereditary tendency.[1] Such juvenile habits as thumb- or lip-sucking may also have some slight influence in producing malformations of the jaw.

Incorrect conformation of the teeth in the two jaws may result in lateral pressure upon the teeth during chewing. In consequence the affected teeth may be moved in their sockets; the junctions between teeth and gums are widened and pockets formed in which food is retained. The irritation arising from the retention of material contributes to the development of pyorrhea alveolaris.

The teeth are capable at any period of life of slowly moving in position in response to pressure. When teeth are extracted from one jaw the opposing teeth in the opposite jaw, thus relieved from pressure during chewing, tend to grow outward, exposing the neck and so predisposing to decay in this region. When a tooth is extracted the teeth in the rear tend to move forward to fill in the gap; this tendency to

[1] As in the case of the famous Hapsburg jaw of the Spanish royal family.

change of position, unless opposed by properly designed bridgework, may disturb the conformation of the teeth. Incorrect opposition of the teeth occurring in childhood can often be corrected by orthodontial manipulation, usually with the use of metal braces applied to pull the teeth into more normal positions.

Decay of the Teeth.

Unlike other structures of the body, a tooth does not repair itself after injury. When the skin is broken, healing takes place and a new

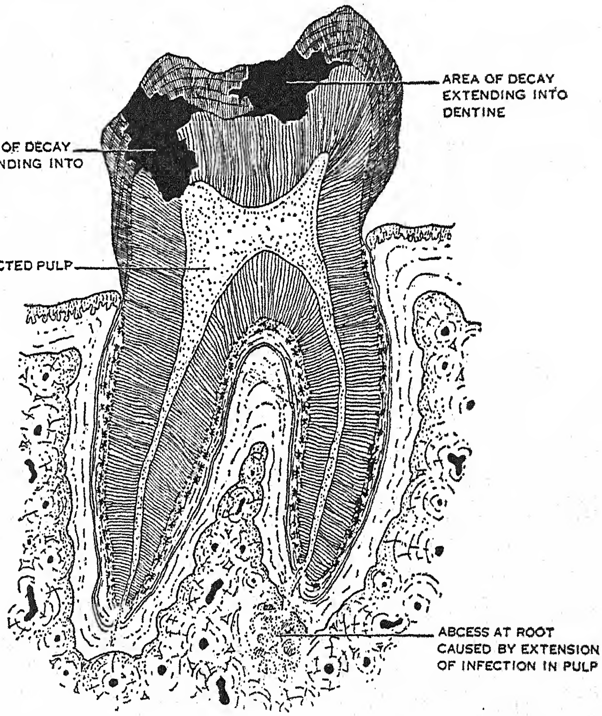


Figure 5. Longitudinal Section of Decayed Tooth.

layer is formed, but when the enamel is removed from a tooth it is not restored. When the dentine is exposed, the delicate proliferations of the pulp in the tubules of the dentine are laid bare, and there is then as much opening into the flesh as in a sore on the surface of the body. An open wound in the skin leads to no serious consequences if it can be kept perfectly clean, that is, surgically clean, and hence free from bacteria. It is impossible to keep the mouth clean even with the greatest care; only a small proportion of the population use tooth

brushes and dental floss, which at best do not effect perfect cleansing. The use of antiseptic mouth washes does not rid the mouth of bacteria. The antiseptic may kill the bacteria that are freely exposed upon the surface, but it cannot reach those in decaying areas of the teeth or in the space between the gums and the teeth. A decaying tooth is, under all circumstances, an infected wound.

Decay of a tooth, called dental caries, starts when and where the enamel is broken down, exposing the dentine to bacterial infection. The causes of the destruction of the enamel, although of primary importance in any effort to prevent decay, are not yet fully understood. Great emphasis has been put upon the importance of keeping the teeth clean. Certainly lack of cleanliness, which permits particles of food to remain between or about the teeth to ferment and decompose, is a contributing factor to the destruction of the enamel. The fact remains, however, that a "clean" tooth may decay. Many people, scrupulous in the hygiene of their teeth, suffer extensively from caries, while others who never brush their teeth may have little decay, although they would have less if they kept their teeth clean.

The cause of caries has usually been sought in some local disturbance to the surface of the fully developed tooth, but it seems more probable that the real cause lies deeper and has to do with abnormalities in the development of the tooth. Dietary deficiency in the early years of life, when the dentine and enamel are forming (see Table I), appears to be the most important condition predisposing to early and excessive caries. Deficiency of calcium and of Vitamins A, C and D (see pages 103, 106) may be followed by roughened enamel which tends to retain food particles and bacterial deposits on its surface, by thin or imperfectly formed enamel which breaks down more readily than normal enamel, and by soft dentine which offers little resistance to the invasion of bacteria after the enamel has been penetrated. But even with adequate diet these same defects may occur as the result of disturbances in the glands of internal secretion. As yet there is no known way of controlling such endocrine disturbances; but fortunately the more prevalent dietary deficiencies can be prevented. The critical period is before birth—the diet of the mother—and during the years of infancy and childhood. When the teeth are fully formed, dietary deficiency, unless unusually extreme, plays little part in causing dental disease. The adult cannot prevent or retard caries by enriching any ordinary normal diet with calcium and vitamins unless the demand on the body for these substances is excessive, as in the case of women who are pregnant or who are nursing infants (see page 104).

The break in the enamel, which is the starting point of caries, is at first small; it may, indeed, be invisible in size and still be large enough to allow bacteria to reach the dentine. The bacteria, which are always present in the mouth, invade the soft flesh in the tubules leading to the pulp cavity. The dentine in the affected area becomes discolored and eroded, the enamel breaks away about the decaying area and a visible cavity is formed. The tooth may then become painfully sensitive to heat or cold or salt or sugar, which irritate the pulp within the tubules of the dentine. It is at this stage, or better even before, that the remedial filling of the teeth produces the best results. The decayed dentine is carefully removed, the clean surface coated with insulating cement, and the cavity filled with gold, amalgam, or other suitable stopping material. If filling is neglected the decay continues; the dentine is destroyed until the pulp cavity is exposed and infected by bacteria.

Dead Teeth and Infection.

Inflammation follows the invasion of the pulp and causes severe toothache which may last from a few hours to a few days. When a decaying tooth has once ached for any lengthy period, thus showing that the pulp is involved, the time for really saving the tooth has passed. To fill such a tooth, it is necessary to kill it by removing the nerve and pulp and plugging the central cavity and its extensions into the roots, a procedure difficult to perform successfully. By so doing all nourishment is cut off from the crown, and the root is supplied only from the outside by the vessels which line the socket. A devitalized and properly filled or crowned tooth may last for a number of years, especially if the devitalization has followed an accidental injury rather than decay. But even under the best circumstances a dead tooth is a foreign body, a more or less clean splinter of bone projecting into the jaw which at any time may become the seat of bacterial action. No pain or other warning symptoms referable to the tooth may arise from such infection. Its source is then difficult to detect except by X-ray examination which is advisable yearly as a safety measure for all devitalized teeth.

A tooth which has decayed into the pulp cavity and is not removed or successfully treated, sooner or later forms an abscess. The pulp with its nerves and blood vessels dies and putrefies and a mass of septic material extends to the ends of the roots where it is in contact with the jaw bone. An inflammation then develops which may follow one or the other of two courses.

If the inflammation is acute, pus forms in considerable quantities at the tip of the root and eventually partially destroys the bone, forcing

its way to the outside, making a channel into the mouth, nose, or sinuses, or through the surface of the skin over the jaws. The drainage of pus relieves the pressure, and the pain and swelling then disappear; but unless the diseased tooth is removed and the abscess at its root cleaned away, the infection may persist and pus continue to form and drain away.

In the second type of abscess formation the inflammation is less acute; the bacteria causing it are of a kind that do not produce much pus. A passage is not formed to the outside; at most, some pus collects under the gum to form a swelling known as a gumboil. When an abscess does not drain, the products of bacterial action, even the bacteria themselves, may enter the blood stream or lymph vessels and so be disseminated throughout the body. Serious general diseases such as arthritis and inflammation of the heart (subacute bacterial endocarditis, which see) have been attributed to infection entering through abscessed teeth. Fortunately, only a small portion of untreated individuals develop these serious diseases in direct consequence of dental caries, which is the most common disease of man and probably has been from prehistoric times.

Pyorrhea Alveolaris.

A common disease of the teeth but one not caused by decay is pyorrhea alveolaris or pus formation between the teeth and gums. This disease is primarily a chronic inflammation of the gums, a gingivitis. It is believed that ill health and dietary deficiencies, especially lack of vitamin C, predispose to the disease by lessening the reparative abilities of the gums so that they are unable to resist in a normal manner the local irritation to which they are subjected. A common cause of such irritation is the deposit of tartar about the necks of the teeth. Tartar is a mixture of calcium salt and organic matter that separates from the saliva; it is removed by the so-called prophylactic treatment applied by the dentist. Other sources of irritation are faulty dental work, such as ill-fitting crowns and bridgework, rough and projecting fillings, undue pressure on a tooth as the result of improper "bite," and the accumulation of food in pockets between the gums and teeth.

As the gums become inflamed their margins about the teeth appear redder than normal; they are swollen and bleed easily. Infection may then occur; pus is formed about the teeth and exudes over the margins of the gums. The infection gradually spreads downward, destroying the bone; the gums recede and the teeth become loose. The pus

formation may be very extensive, and in consequence, the breath is made foul and health is impaired.

Trench mouth, Vincent's angina or ulceromembranous stomatitis is a condition in no way related to pyorrhea. It is a bacterial infection spread by contact which occurs particularly between the ages of sixteen and twenty-five. The gums become swollen and ulcerated. The sores are covered with a whitish membrane. The disease may extend to the cheeks and tonsils.

Foul Breath.

The source of most foul breath is to be found in the mouth and surrounding structure. Food retained between the teeth, in pockets between the teeth and gums, and in the papillae at the base of the tongue, may putrefy, fouling the breath. The retained food material may have an odor of its own which is imparted to the breath, as in the case of onions, garlic, and spiced candies. Infection of the tonsils, or any other structure of the mouth or respiratory tract, may be a source of odor —as is pyorrhea. Sometimes the smell on the breath comes from odoriferous material carried in the blood and aerated out in the lungs; such is the source of the odor following ingestion of alcoholic beverages, large quantities of essential oils, and certain chemical compounds.

Hygiene of the Teeth.

Hygiene of the teeth is no longer the simple matter of cleanliness once optimistically advocated in the slogan, "a clean tooth never decays." The first step in dental hygiene is to obtain as sound teeth as is possible with proper diet in the early years of life. The second—of highest importance—is constant supervision and repair by a competent dentist. The third is cleanliness. And the fourth is the avoidance of contact with materials known to be detrimental to the teeth.

When the food is coarse and fibrous, it exerts a scouring action while it is being chewed which is lacking when the food is soft and rich. It is thus necessary to take active measures to prevent the accumulation of fermentable material about the teeth; the toothbrush and dental floss serve this purpose. But in the few minutes of their daily use they do not supply the thorough kneading of the gums important to their health that is provided by firm coarse foods, of which the apple is an especially good example.

In certain occupations the enamel is worn from the teeth through contact with metal. This occurs among workmen who hold nails in the mouth to facilitate rapid work, as do shoemakers and those en-

gaged in nailing lath and shingles. In other industries the enamel of the teeth may be ground away by sharp particles of dust which enter the mouth. Such substances are graphite, coarse metal dust, sand and the like. In sugar refineries the inhalation of sugar dust may lead to rapid decay. Lead and mercury have a detrimental action upon the teeth which leads to pyorrhea, as in plumbers, typesetters, painters and potters. Those who work with white phosphorus are exposed to a particular danger unless their teeth are kept clean and in excellent repair. The decay which results from phosphorus does not stop with the tooth or its socket, but involves the entire jawbone, causing so-called "phossy jaw." The enamel of the teeth may become permanently stained with yellow spots as the result of drinking water containing even small amounts of fluorine (1 part in 1,000,000). In some parts of the United States the water supply contains appreciable amounts of fluorine.

Chemical Digestion in the Mouth.

The processes of digestion in the mouth are not entirely mechanical, for it is here that food comes in contact with the first of the digestive fluids—the saliva. In the walls of the mouth cavity there are many small glands which produce fluid, but most of the saliva is formed in three pairs of glands which discharge their secretions through tubes into the mouth cavity. The largest of these paired glands, the parotids, are located directly under the lobes of the ears and are familiar as the site of mumps, in which disease they are swollen and painful. The ducts from the parotid glands extend directly forward through the flesh of the cheeks, opening into the mouth about on a line with the anterior molar teeth; the slight protuberances about the outlets of the ducts make these localities the ones most commonly caught between the teeth and injured slightly when the "cheek is bitten" in chewing. The sublingual and submaxillary salivary glands lie within the arch of the lower jaw; their ducts discharge beneath the tongue. (See Figure 6.)

The flow of saliva is normally stimulated by nervous response to the presence of material in the mouth; the amount and consistency of the fluid are determined by the nature of the substance exciting the flow. The saliva formed by the different glands varies somewhat in nature; that from the parotid glands is thin and watery (diluting saliva), while that from the sublingual and submaxillary glands is more viscous (lubricating saliva). No saliva is produced following the introduction of water; but sour, bitter or salty fluids, which must be diluted and washed away, induce a copious flow particularly from the

parotid glands. Similarly, dry but unappetizing substances, such as sand, excite a profuse discharge of thin diluting saliva which aids in their ejection from the mouth. If, on the other hand, the substance is edible, the saliva is more viscous. The amount secreted varies with the dryness of the material; sufficient saliva must be added to soften and lubricate the food in order that swallowing may take place.

The nervous reflex which controls the flow of saliva acts through a center in the brain. This center responds to impulses coming from

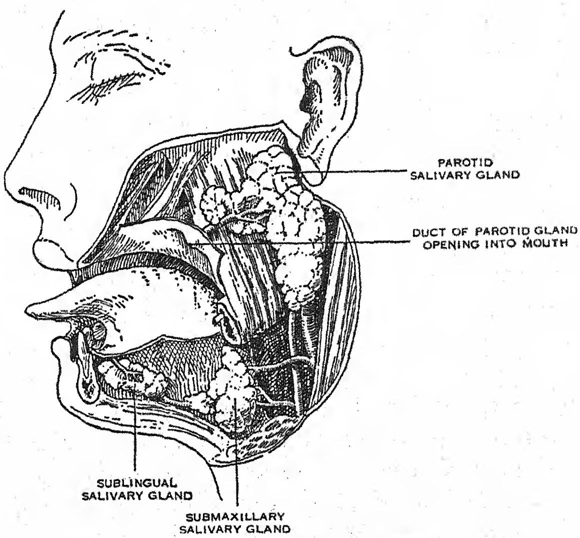


Figure 6. SALIVARY GLANDS.
Dissection of the face showing salivary glands of the left side.

other parts of the brain as well as those coming from the mouth. Thus emotion may influence the flow of saliva. A person who has a keen appetite does not need to place food in the mouth to stimulate the flow; the sight, smell, or even the thought of some savory substance will "make the mouth water." Conversely, strong and disagreeable emotions, such as fear and worry, diminish or stop the flow of saliva even in the presence of stimulating substances.

One of the earliest judiciary measures took cognizance of the suppression of salivary secretion by fear. The "ordeal" consisted in filling the mouth of the suspected person with flour; if he were innocent, and therefore not fearful, the flow of saliva was normal and he masticated and swallowed the flour; if he were guilty, his fear resulted in an inability to moisten and swallow it. While this test is sound

physiologically, it must have condemned many innocent persons of anxious temperament and have exonerated the guilty, if bold. The effect of emotion on the flow of saliva is seen in the embarrassed public speaker whose mouth becomes dry, and in the scolded child who licks its dry lips and gulps in the effort to swallow with a dry mouth. If the fear is aroused by a scolding at meal time, digestion may be disturbed. Emotional influence upon secretions is not limited to the salivary glands; it affects also the glands which secret digestive fluids in the stomach and intestine; it is therefore in the interest of good digestion that meal times should be free from worry and other unpleasant emotional disturbances and also from study or mental concentration. Pleasant emotions, contentment and joviality do not interfere with the secretion of digestive fluids.

The quantity of saliva secreted daily is widely variable but averages about 1500 c.c. It may be abnormally diminished at the onset of fevers, and also as the result of deprivation of water, prolonged diarrhea or vomiting. Intense thirst results. On the other hand, the quantity may be abnormally increased as the result of mercury poisoning and certain diseases of the nervous system; the salivation may then amount to as much as 5000 to 10,000 c.c. a day.

The chief value of saliva consists in moistening the food and lubricating it for swallowing; the digestive function is less important. Little actual digestion of starch from the action of the enzyme ptyalin occurs in the mouth, for the food does not stay there a sufficient length of time. The main salivary digestion takes place in the stomach, where it continues until the food is rendered acid by the gastric secretion.

Swallowing of Food.

From the mouth and pharynx the food passes to the gullet or esophagus and down into the stomach. The esophagus is a soft muscular tube whose function is purely one of transportation, since it plays no part in the chemistry of digestion. In the act of swallowing, the bolus of finely divided food, saturated with saliva, is first gathered well back on the top of the tongue; the edges of the tongue are next brought up tight against the roof of the mouth to prevent food from escaping back into the mouth; then a sudden upward and backward movement of the tongue projects the food toward the esophagus.

Behind the mouth is the throat or pharynx, and the food must pass through this cavity to reach the esophagus. Passages which lead to the nose and lungs also open into the pharynx. To prevent food from

being forced up into the nose, the soft palate rises and occludes the nasal passage; at the same time the windpipe or trachea is shut off

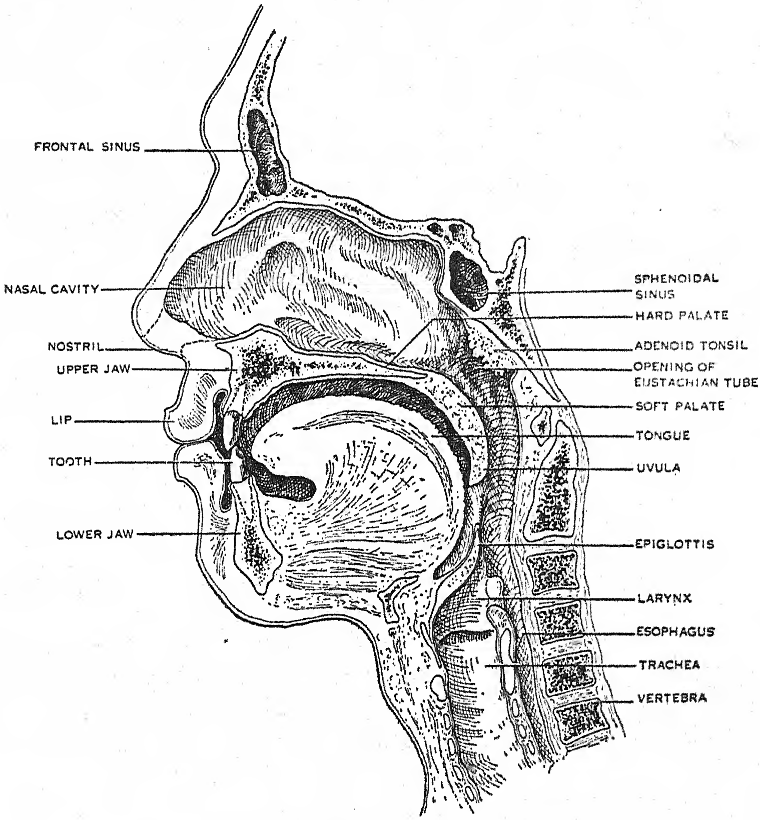


Figure 7. SAGITTAL SECTION OF HEAD.

The primary passages shown are the esophagus, leading to the stomach, and the trachea, leading to the lungs. At their upper ends the trachea and esophagus join to form a common passage, the pharynx, which opens into the mouth and nasal cavity. The common passage necessitates an arrangement through which food may be directed into the esophagus; this is accomplished by the act of swallowing. Except during swallowing the esophagus is closed by the apposition of its walls.

Passages lead from the nasal cavity into the middle ears (the Eustachian tubes), and also into the sinuses. Although the frontal sinus is shown, the passage to it does not fall in the line of section; see Figure 33.

The adenoid tonsil is shown on the rear wall of the nasal portion of the pharynx.

by a lid-like flap, the epiglottis, against which the larynx is pushed during swallowing. The food is left only one channel to follow, that

into the esophagus. Swallowed liquids may be projected the full length of the esophagus under the impetus given them by the tongue. Solid foods are conveyed to the stomach by wave-like muscular constrictions, called peristalsis, in the wall of the esophagus.

On reaching the lower end of the esophagus the food passes a muscular valve which, when closed, shuts off the opening into the stomach. Through this valve material passes slowly and more or less continuously in distinction to the intermittency of swallowing. As a result of hasty eating or swallowing large mouthfuls, food may accumulate in the lower end of the esophagus and give rise to an unpleasant sensation of fullness. Successive swallows of small amounts of fluid tend to hasten the passage through the valve into the stomach; it is for this reason that some persons who bolt their food facilitate its passage by sipping water after each mouthful. The indigestion which may result from their imperfect mastication has been quite erroneously attributed to the water, and, in consequence, the belief has grown up that drinking water during meals is harmful. This belief is false. There is no harm whatever in drinking water at meals, provided the water is not used as a substitute for chewing and is taken only when the mouth is empty. So far as digestion is concerned, water is no different from any other fluid, bouillon, tea or coffee, taken at meals even by those who avoid water at this time.

The passage of food through the esophagus is rarely interfered with except in the case of partial or complete occlusion of the tube by tumors, or by scars following injury from corrosive substances such as strong alkalies or acids. When occlusion is complete, food can be administered only through an opening, made by surgical operation, in the anterior wall of the body and stomach. Aside from the carbolic acid taken with suicidal intent, the most common agents causing corrosion of the esophagus are muriatic acid, used as a soldering flux, and household lye. Careless adults sometimes mistake the acid for a beverage; it is a common accident for small children to drink the strong solution of caustic lye used to clean household drains.[1]

The act of swallowing is complex, but its coordination is rarely seriously disturbed. Paralysis of the muscles of the pharynx, as the result of diphtheria, may prevent the proper closure of the opening from the throat into the nasal passages so that a portion of the food is forced out through the nose. This same regurgitation may occur as

[1] Less so now than formerly, since a federal law requires suitable warnings on the containers in which such substances are dispensed.

an occasional and temporary disturbance in infants; it may also take place as a result of muscular incoordination in drunkenness.

In the normal adult food or drink may occasionally enter the windpipe, usually as the result of laughing during swallowing. Any irritation in the windpipe at once excites coughing. The sharp blast of air occasioned by the act usually removes the misplaced material. If the body lodged in the trachea is solid and bulky, death from strangulation may follow. An unconscious person cannot cough and cannot swallow and hence may be strangled by artificial teeth or tobacco present in the mouth. In giving first aid to those who are unconscious, as from gas poisoning or drowning or deep alcoholic intoxication, it is advisable to place them in the prone position so that the tongue, saliva, and any foreign material in their mouths may fall forward instead of backward into the pharynx (see page 263). No fluid of any kind should be given to an unconscious person; it is as apt to run into the trachea as into the esophagus. The practice of forcing water, or especially brandy or whisky, between the teeth of an unconscious individual to revive him is not merely undesirable—it may be fatal.

Function of the Stomach.

The stomach is not an absolutely indispensable organ of digestion, for the chemical transformation of the food which takes place there can be carried out equally well by the intestines. Life can continue and the essential minimum of digestion may take place after complete removal of the stomach. The unfortunate who has suffered this loss is, however, seriously inconvenienced, since his diet is restricted to gruels which must be taken in small quantities at frequent intervals. The stomach acts as a protective organ to the intestines and as an organ of convenience. It is a reservoir into which large quantities of food may be taken at convenient intervals; this food is then reduced to a gruel-like state suited to the action of the intestines and passed into them at a rate compatible with their capacity.

Filling of the Stomach.

The stomach is a distensible muscular pouch; its size is determined entirely by the volume of food which is in it. In the morning before breakfast the stomach contains only a few ounces of fluid and some bubbles of swallowed air. The organ appears then as a wrinkled tube extending from the point at which the esophagus passes through the diaphragm to the beginning of the small intestine. Shortly before the

usual hour for breakfast, if no food is taken, the muscular walls of the stomach contract; this active contraction of the stomach is associated with sensations of hunger. Food entering the stomach distends it, and the stomach relaxes to hold the material, gradually assuming, as the addition of food is continued, a shape somewhat resembling that of a pear. The more distensible and therefore larger end, the fundus, lies to the left behind the lower ribs; the esophagus opens into it. The smaller end to the right, called the pylorus, tapers into the small intestine. The passage from the stomach to the intestine is closed by a

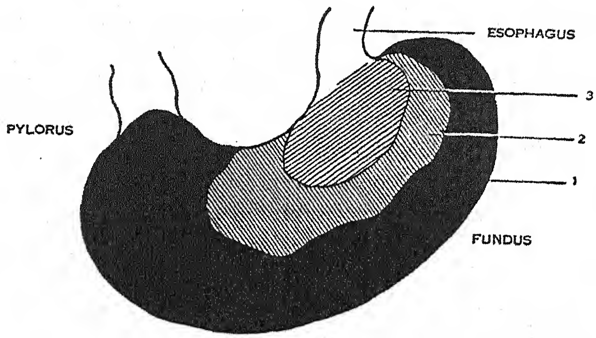


Figure 8. Filling of the Stomach.

Section of a rat's stomach showing stratification of food given at different times. The food was given in three portions, indicated by the differently shaded areas, in the order designated by the numbers.

valve. This valve consists of circular bands of muscle within the wall of the stomach; such a valve is known as a sphincter. Contraction of the muscle squeezes the pylorus shut in a manner analogous to closing the mouth, the bladder, and the anus. The pyloric sphincter under involuntary nervous control opens to allow food, suitably prepared by the stomach, to pass into the small intestine.

The bulk of the food reaching the stomach during a meal accumulates in the fundus. Each successive portion swallowed passes into the center of the mass already there. As a result, the food is deposited in layers. That which has been in the stomach the longest is in contact with the walls, from which is poured the acid digestive fluid, the more recent additions of food near the center of the mass may escape acidification for a half hour to two hours. During this time salivary digestion continues and much of the starch is converted into assimilable sugar.

Digestion and Absorption in the Stomach.

The digestive fluid of the stomach, gastric juice, is secreted in minute glands imbedded in the wall of the stomach and opening through individual ducts into the stomach cavity, much as sweat glands open to the surface of the skin. Some of the glands secrete fluid containing the enzymes rennin and pepsin. Rennin acts to curdle milk and thus makes a solid more readily handled and separated from water; pepsin digests protein material. Other glands secrete hydrochloric acid, for pepsin, unlike the digestive enzymes of the saliva and intestinal fluids, acts only in an acid medium. The gastric juice is sour as secreted, for it contains nearly 0.5 of one per cent of hydrochloric acid. The concentration in the stomach contents is lower, 0.1 to 0.2 of one per cent, for the food dilutes and combines with the acid. Still other gastric glands secrete the mucilaginous mucus which surrounds and makes slimy the particles of food.

The stimuli which control the flow of gastric juice are similar to those which control the flow of saliva in the mouth. The presence of food in the stomach is the primary stimulant. The taste, smell, or even the thought of food may, however, initiate the flow. Hunger thus expedites digestion. The niceties of preparing and serving food have more than artistic merit; they actually assist the flow of gastric secretion, a point of special importance in feeding invalids with fickle appetites. Distaste, worry, fear and other strong unpleasant emotions, and also fatigue, may diminish or prevent the secretion of gastric juice.

Normally the flow of gastric juice continues until the stomach contents are saturated and rendered acid. Little is required to render carbohydrates acid; much more for proteins since they combine with considerable quantities of acid. Meat induces a greater flow of gastric juice than does starch or sugar, but in spite of this increase, proteins stay longer in the stomach than do carbohydrates. Fat may remain even longer; and this peculiarity gives rise, in part, to the feature known as the richness of foods, such as is experienced in eating suet puddings and fat meats. A bulky meal of soup and crackers soon brings repletion, but as the material is quickly acidified and passed from the stomach, hunger returns in a short time. It does not after a meal of pork and plum pudding. In the vernacular, fatty foods "stick to the ribs."

Intense sweating reduces the acidifying and digestive powers of gastric juice and digestion may cease entirely under heavy muscular work (see page 142). Poorly masticated or compact moist foods are slow in

becoming saturated with gastric juice and remain in the stomach for a longer time than do well-chewed and porous foods. Thus toast, because of its dry and porous state, more readily absorbs the gastric juice than does moist fresh bread.

Whether or not the stomach will empty itself completely of one meal before the next is taken depends upon the length of the interval between meals and the conditions governing the rate at which food passes through the stomach. One important factor is the amount of food taken; other things being equal, the larger the meal the longer it will remain in the stomach. Meals of approximately one-third the daily food intake may not disappear entirely from the stomach under six or seven hours. The stomach, contrary to popular belief, does not need a rest between meals; it is taxed more by large meals taken at long intervals than by small meals at short intervals. Invalids, and those with diseases of the stomach, and also infants and aged people, are best fed at short intervals with small amounts at each meal. The same rule applies advantageously to active growing children who consume large quantities of food. Limiting food intake to two or even three meals a day is not conducive to the greatest ease of digestion or the most efficient utilization of the food eaten (see page 74).

The absorption of food substances from the stomach is very slight as compared with that from the intestines. Pure water is not normally absorbed at all but is passed through rapidly to the intestines. Alcohol and certain poisons may be absorbed directly from the stomach.

Movements of the Stomach.

There is never a general churning or mixing of the accumulated material in the fundus. The walls of this part of the stomach contract gently upon the mass and express the more liquid portions, moving them toward the pyloric end. Here they come in contact with the walls of the stomach and are exposed to the gastric juices. The movements in the pylorus are forcible; the walls contract rhythmically in successive rings which travel slowly as a wave-like movement toward the intestinal valve. As digestion progresses the contractions become stronger. With each wave the stomach walls meet near the outlet and form a pouch shut off from the rest of the stomach. By the contraction of the walls of the pouch upon the material which has collected in front of the pyloric valve, a considerable pressure is developed. This pressure tends to force open the valve, but whether it

will relax and allow material to be squirted into the intestine depends upon a number of factors which operate together to regulate the passage so that the food passes only after it has been properly prepared by the stomach and at the slow rate suited to the capacities of the intestines. One of these factors is the presence of acid material in the first part of the small intestine. The acidity increases the tonicity (the firmness of the muscle) of the valve so as to prevent the further passage of material until that already received in the intestines has been rendered alkaline and moved along to make room for more. Likewise the tonicity of the valve appears to be increased by the presence of solid and incompletely disintegrated particles of food in the pouch of the stomach before the pyloric valve. If the material in the pouch is of the proper consistency, and if the intestines are prepared to receive it, the sphincter relaxes and the material is squirted from the stomach into the intestines.

The movements of the stomach depend upon the activity of the muscle in its walls; this muscle, like others in the body, is weakened during illness. Consequently for invalids the diet must be adapted to the decreased vigor of the stomach. The sensation of hunger depends upon vigorous muscular contractions of the stomach; it is therefore diminished or absent during illness.

In contrast to this weakened state the tonicity of the stomach may be abnormally increased; the pyloric valve is then tightly closed and the waves of muscular contraction are abnormally forceful. The cramp-like contractions give rise to severe intermittent pains—gastric colic. This condition may result from disease states, such as gastric inflammation and ulcers; it may also be due to indigestible material in the stomach, as in the green-apple stomach-ache. It is common in infants and in them is usually accompanied by regurgitation of food.

The Capacity of the Stomach.

The normal capacity of the stomach, when filled by a meal, ranges from a few ounces in an infant to 1.5 to 2.0 quarts for an adult male, the female stomach being somewhat smaller. The habitual intake of unusually large amounts of solids or fluids into the stomach, as in heavy beer-drinking, may lead to gradual increase in the size of the organ, hypertrophy, without causing what is technically called dilatation; the muscular strength is maintained and the stomach merely grows larger to accommodate a greater amount of material. Dilatation, on the contrary, is not an increase in substance, but a stretching and

weakening of the muscles. Any hollow muscle of the body—the heart and the bladder as well as the stomach—may show either dilatation or hypertrophy. The dilated stomach is large and flabby and may be incapable of emptying itself completely.

Dilatation of the stomach may develop rapidly—acute dilatation—as in a boy who gorges himself in an eating contest; it may occur, for reasons yet unknown, after surgical operations, and occasionally in apparently normal individuals. Such acute gastric dilatation is often a serious condition. More often, however, dilatation develops slowly and as the result of retarded emptying of the stomach. Cancer or ulcer in the pylorus may lead to a partial occlusion of the valve, as may also less serious conditions, such as tightly laced clothing, or gastroptosis. Gastroptosis means fallen stomach and is a condition in which the fundus sags downward. The pyloric end of the stomach is firmly fixed in place by supporting ligaments. The gastric displacement may result in a sharp angle at this attachment; the kinking delays the passage of food. Gastroptosis occurs much oftener in women than in men. Improper standing posture, weakened abdominal walls, and a state of general debility contribute toward its occurrence. Those affected often stand in a characteristic position, the head and shoulders are stooped, the abdomen is thrust forward, and the back bent to maintain balance. A similar slouching posture has been affected in recent years as a pose of fashion.

In gastric dilatation the stomach fails to empty completely and the contents therefore stagnate and ferment. The acid gastric juice possesses strong antiseptic powers and kills most of the bacteria and other organisms carried in with the food, so that the material which passes to the intestine is usually sterile. Prior to its saturation with the acid secretion the growth of organisms continues. When material is retained in the stomach for an unusual length of time fermentation progresses energetically.

Hyperacidity.

The belief is widely held that gastric discomfort is frequently due to an abnormally acid state of the gastric juices, hyperacidity. Actually the gastric juice as secreted is never abnormally acid, but in certain conditions the stomach contents do become excessively acid. This hyperacidity occurs far less often than might be judged from the large number of people who complain of this condition and who swallow sodium bicarbonate to relieve the symptoms of an imagined "acid

condition"; their discomfort is usually due to nervous indigestion. Modern advertising, with its emphasis upon hyperacidity, has done much to extend the belief in this condition, which, when it does occur, can be found out only by analysis of gastric contents removed with a stomach tube. Hyperacidity, when actually demonstrable, results, not from a too acid gastric juice, but from an oversecretion of gastric juice or a delay in the emptying of the stomach which allows the gastric juice to accumulate. Hyperacidity of itself does not give rise to the symptoms which are often attributed to it, pain and heartburn, for the lining of the stomach is not irritated by gastric juice in full strength. Such symptoms are usually due to disturbances in the tonicity of the stomach muscle arising from nervous causes.

Ulcers of the Stomach.

The wall of the stomach is occasionally scratched and cut by rough particles in the food, but such injuries heal readily in spite of the presence of fluids which will digest all other flesh. There has been much speculation as to why the stomach does not, even aside from such raw places, digest itself. It is generally believed that the cells of the stomach protect themselves by producing anti-enzymes which inhibit the action of the pepsin on them. After death the stomach wall is as digestible as any other meat, as is witnessed by the use of tripe as an article of diet. Occasionally, in spite of the normal safeguards, self-digestion does occur during life with the production of so-called gastric, peptic, or acid ulcers. These are not temporary injuries which heal readily, but chronic sores which persist for a long time and heal with difficulty.

An ulcer is a hollowed out place in the flesh; those of the stomach appear as small excavations extending deep into the wall of the organ. Their usual location is near the pylorus; occasionally similar ulcers appear just beyond the valve and are then known as duodenal ulcers. The cause of ulcers has not been determined although numerous theories have been advanced, all of which are concerned with the manner in which the protection against autodigestion is lost in the area where the ulcer develops. It has been suggested that the blood supply is interfered with; that nervous changes are the cause; and that infection or the products of infection are responsible. It is now recognized that an hereditary predisposition may exist and that ulcers occur most commonly in high-strung emotional individuals, especially if they are subject to unusual responsibilities and worries. Ulcers are most frequent between the ages of twenty-five and forty-five.

Pain is the commonest symptom of ulcers; it may appear immediately after eating or be delayed for two or three hours. It results, in part, from the irritation of the raw area by the acid of the gastric juice, and in part from the strong contractions of the muscles of the stomach. Since ulcers are usually near the pylorus, the valve is stimulated by their irritation to become abnormally tense; the evacuation of the stomach is slowed and the acidity of the contents, in consequence of the delay, becomes abnormally high.

Pain in the alimentary tract is not always felt at the point at which the pain arises; instead it may be referred (see page 349) some distance and may even be felt on the surface. Thus the pain of ulcers, or of any stomach disturbance, is felt most keenly near the tip of the breastbone; pain from the small intestine is felt in the mid-line of the abdomen, usually near the navel; from the appendix (see page 59), on the right lower side of the abdomen; from the large intestine, in the region of the lower ribs on the right or the left side—when on the left side it is sometimes mistakenly believed to arise from the heart.

Vomiting.

When irritating or indigestible material is swallowed, or the stomach is overdistended, this organ may protect itself from injury by expelling its contents in vomiting. This act is a complex series of movements of respiratory and abdominal muscles and of the stomach itself, controlled and coordinated by a special center in the brain. This center can be stimulated reflexly for other organs than the stomach. Thus a blow in the abdomen or on the head, severe pain, tickling the back of the throat, prolonged coughing, may cause vomiting. Indeed, the mere thought, or sight, or smell of disagreeable material may result in nausea and vomiting. The act is induced by numerous drugs called emetics; some emetics, such as mustard, irritate the stomach, while others, such as apomorphine, act upon the vomiting center in the brain. Vomiting may occur from reflexes arising in the heart and hence is an accompaniment of certain types of heart disease; it may result also from disturbances in the organs of equilibrium, the semicircular canals of the inner ear. Disturbance of the semicircular canals leading to vomiting is seen most commonly in seasickness, less often in car sickness and elevator sickness (see page 424).

The act of vomiting is usually preceded by changes in many bodily functions, giving the sensation known as nausea. In this state contractions of the stomach are stopped; a sinking sensation is experienced

in the pit of the stomach; the skin becomes pale; sweating occurs; the muscles become weak; breathing is rapid; the saliva is increased; and yawning frequently occurs.

There are two general types of vomiting: one, projectile vomiting, and the other, the more usual type associated with retching. In both varieties the opening from the stomach to the intestine is tightly closed and the valve to the esophagus relaxed. In projectile vomiting sudden waves of the stomach, running in a direction opposite to the normal, squeeze out the stomach contents through the esophagus. Such vomiting is sudden and effortless. More commonly, however, the respiratory and abdominal muscles cooperate to make the procedure far more complicated. In the usual type of vomiting the pyloric valve is closed and the esophageal valve is opened, as in the projectile type, and then a deep breath is taken, after which the windpipe is shut off by the glottis so as to hold the thorax rigid. Spasmodic contractions of the abdominal muscles, the act of "retching," exert pressure against the stomach and force the contents through the esophagus.

Nervous Indigestion.

"Nervous indigestion," so called, is probably the commonest form of persistent gastric disturbance. The condition is characterized especially by discomfort after meals, and is often associated with distention, eructation of gas and "heartburn."

Nervous indigestion is due not to any fault of the stomach, but rather to the conditions under which this organ is forced to function. Many of the circumstances of modern life are conducive to nervous indigestion; worry, nervousness, excitement, overwork, and the excessive use of alcohol, coffee, tea and tobacco are the most common causes.

Nervous indigestion results from disturbances in the coordination of the activities of the stomach. Many of the symptoms are due to the improper nervous regulation of the valve which closes the passage from the esophagus to the stomach. This valve may become tense, and open insufficiently to allow the passage of food into the stomach, so that both solids and liquids collect and distend the lower end of the esophagus, giving rise to a feeling of discomfort. On the other hand, the valve may relax unduly so that acid material from the stomach is regurgitated into the esophagus, giving rise to a stinging sensation known as "heartburn." This condition has no relation to the heart other than the general locality to which the sensation is referred.

During swallowing more or less air is carried with the food into the

stomach and collects in the upper part near the esophageal opening. Passage of the gases as an eructation usually takes place with comparative ease. Individuals suffering from nervous indigestion may eructate habitually and in a short time raise quantities of gas many times the volume of the stomach. Severe and prolonged attacks of belching are usually associated with the swallowing of air, and if the individual in whom they occur is watched closely it will be seen that swallowing movements regularly precede the eructation. The unconscious swallowing of air can be prevented and eructation stopped by holding the mouth slightly open with an object, such as a pencil, placed between the teeth.

Gastritis.

The stomach is a remarkably efficient organ and usually fulfills its functions with little indication of its presence. The tolerance of the stomach, however, is frequently abused by irritating substances taken in the diet. As a result, a so-called simple acute gastritis is developed and may exhibit any degree of severity in its local and general effects, from the discomfort of a "green-apple stomach-ache" to the prostration of so-called ptomaine poisoning. The general state of health and such conditions as hot weather or hot workrooms influence the susceptibility to acute gastritis. The direct exciting cause may be one of many: coarse and indigestible food, excess of food after a prolonged fast or fatigue, food or drink at extremes of temperatures, corrosive substances such as acids or alkalies, the salts of heavy metals, alcohol, spices, and many drugs. Perhaps the most common cause is tainted food which is rendered irritating either from the products of previous bacterial action or from the action of the bacteria after they reach the stomach. Repeated acute gastritis of moderate severity may lead to chronic gastritis. Its most common cause is the habitual use of alcohol.

Food Poisoning.

Food may be poisonous (in the broadest use of the word) from a wide variety of causes; the main ones are classified in Table II.

The best known of the poisons inherent in food is that of the mushroom. The variety of mushroom cultivated and sold on the market is never poisonous, but among the many varieties of wild mushrooms there are over eighty poisonous ones. Consequently only the botanically well-informed can safely gather them for culinary purposes. In all forms of mushroom poisoning there is gastric irritation, usually with

TABLE II.—CAUSES OF FOOD POISONING

A. Toxins inherent in the food:
   Resulting in: 1. Mushroom poisoning
   2. Fish poisoning
   3. Mussel poisoning
   4. Potato poisoning
   5. Selenium poisoning
   6. Milk sickness

B. Toxins introduced into the food:
   1. Preservatives
   2. Contaminants and adulterants
   3. Poisons purposely introduced

C. Toxins produced in food by organisms:
   Resulting in: 1. Ergot poisoning
   2. Botulinus poisoning
   3. Poisoning by product of putrefaction

D. Parasites causing specific diseases:
   (a) Occurring in food in natural state:
   Resulting in: 1. Trichinae infection
   2. Tapeworm infection
   3. Septic sore throat
   (b) Introduced into food by contamination:
   Resulting in: 1. Typhoid fever
   2. Paratyphoid and similar diseases
   3. Diphtheria
   4. A variety of diseases more common in the tropical than in the temperate regions: bacillary dysentery, amebic dysentery, undulant or Malta fever, Asiatic cholera and fluke diseases.

cramps, diarrhea, and vomiting. From some varieties of toxic mushrooms, nothing more serious results; but from others, there is profound poisoning which may be rapidly fatal.

Fish poisoning is uncommon except in the West Indies and Japan. In the latter country a serious form occurs from eating a fish of the tetrodon family; in the West Indies the fish responsible is usually the barracuda. The poison of this fish is limited mainly to the sex glands; the rest of the flesh is wholesome. Poisoning from fresh-water mussels shows an as yet unexplained peculiarity; the mussels may be eaten safely at most times, but for no known reason they may suddenly become dangerously poisonous. There have been several extensive outbreaks of mussel poisoning in this country; in some the mortality has reached 15 per cent.

Potato poisoning is rare; it has been known to occur from potatoes grown too near the surface of the ground and showing, in consequence, a greenish skin, and from old potatoes stored in a damp cellar. Milk sickness is now likewise rare, but was in pioneer days the cause of

much loss of life in the eastern half of the United States. Milk sickness is poisoning from an oil contained in white snakeroot or richweed. Grazing cattle do not ordinarily eat this plant except in times of food scarcity. When they do, however, they are poisoned, developing a disease known as the "tremble." Some of the oil passes into their milk; human consumption leads to the serious and often fatal milk sickness.

Selenium poisoning has only recently been brought to attention and so far the disease has been limited mainly to cattle. Selenium is a highly poisonous substance present in the soil of some of the western plains. Grass and cereals grown in these regions may contain selenium and hence be rendered poisonous.

Preservatives and adulterants have long commanded attention as sources of food poisoning, and laws are now enforced to protect the public from this menace. Accidental contamination by toxic substances is less easily controlled; there have, in the past, been wide and serious outbreaks of lead poisoning from cider stored in lead-lined vats, arsenic poisoning from beer in the manufacture of which an impure sulphuric acid containing arsenic has been used, and cyanide poisoning from silver polish incompletely removed from tableware. At present the most serious health menace of this kind is that from fruit which retains on its surface the lead and arsenic compounds used as insecticides and fungicides.

Ergotism, once widely prevalent in Europe, is now a rare form of food poisoning. It is caused by eating bread made from rye blighted with the fungus ergot. The ergot blight, which is extracted and used as a medicinal substance, causes blood vessels to constrict; food poisoning in the past led to loss of legs and arms from the gangrene that resulted.

Botulinism is a far more prevalent and more fatal form of food poisoning. It is caused by a toxin produced by the bacillus botulinus growing usually in imperfectly processed canned foods. A "flat sour" taste and faint odor are often the only indications of this particular putrefactive change. A drop of fluid from the food placed on the tongue, but not swallowed, may cause death. The appearance of the can often gives an indication of the spoiled contents. The normal vacuum is lacking, the ends of the can are bulging instead of slightly concave, and pressure applied to the ends elicits a sharp sound as the tin bends inward. A can in this condition is known as a "bloater," and the contents, although not always contaminated with botulinus toxin, should nevertheless be disposed of in a manner to prevent consumption by domestic

animals, for they, as well as man, are susceptible to botulinism. The toxin of the bacillus botulinus is destroyed by heating for several minutes to the boiling point. It is advisable to boil all canned meats and vegetables prior to consumption, especially if they are home canned.

Poisoning by the products of putrefaction arising from the action of organisms other than the botulinus bacillus is often called ptomaine poisoning. Strictly speaking, however, ptomaine poisoning results only from alkaloidal substances, ptomaines, believed to be formed during the putrefaction of certain proteins, especially those of shellfish. The term has been popularized and is now often used to denote many forms of food poisoning; physicians, however, are discarding the word as scientifically untenable.

Putrefied food usually gives evidence of its undesirable estate by its smell or taste. Such warning is not provided by food which has been contaminated by the parasites that cause specific diseases as tabulated in Section D of Table II. Food poisoning from this source is the commonest variety; it will be discussed in the following chapter under the sections devoted to "Animal Parasites of the Digestive Tract" and "Bacterial Infection of the Digestive Tract."

Food Idiosyncrasy.

By food idiosyncrasy is meant the susceptibility of an individual to poisoning by a certain food that is harmless to most people. The basis of their peculiarity is an allergic reaction similar to that causing hay fever and serum sickness. The symptoms that develop usually consist of hives and, less often, nausea and vomiting. The foods most commonly involved are buckwheat, eggs, milk, onions, oatmeal and fruit, especially strawberries. The subject of allergies is discussed in Chapter XXIII.

Specific food idiosyncrasy must not be confused with the belief held by many persons that some particular article of diet invariably gives them indigestion. Such statements are frequently based on a single experience of gastritis, for the cause of which some article was blamed illogically and shunned thereafter.

There is a common but unfounded belief that some foods taken in combination "upset the stomach." In this belief many people refrain from eating lobster and milk at the same meal, but they enjoy, without qualm, the same ingredients in a more intimate mixture, such as lobster *à la* Newburg. Whatever poisoning occurs from a food combination is due to the putrefaction, infection, or indigestibility of one or both of the articles, and not to an imaginary interaction.

CHAPTER III

DIGESTION AND ITS DERANGEMENTS (Continued)

Small Intestine.

The small intestine is a thin-walled tube twenty to thirty feet in length, extending by a winding course from the stomach to the large intestine. The diameter of the intestine is determined by the bulk of its contents; when well filled it is about an inch across at the stomach end and tapers slightly to its junction with the large intestine.

The intestine is covered with a layer of thin tissue called peritoneum. This layer does not extend completely around the periphery, but is reflected longitudinally in two closely placed layers which thus form a membrane called the mesentery, by which the intestine is attached to the rear of the abdominal wall. The formation of the mesentery resembles a cloth sewed around a piece of pipe; the two edges of the cloth extending away from the seam are comparable to the mesentery. Its width from intestine to the body wall is about ten inches. At its line of attachment to the intestine, the mesentery has the same length as that organ (twenty to thirty feet), while at its attachment along the back of the abdominal wall the mesentery is only about a foot in length. Thus the mesentery presents two borders, one of which is twenty times as long as the other, and, as would be the case with a piece of cloth, the mesentery is puckered or gathered. This puckering corresponds to the convoluted course which the small intestine follows. The mesentery serves both as an attachment to restrain the small intestines and as a support for the numerous blood vessels and nerves which are supplied to this organ. The peritoneum which covers the intestines and forms the walls of the mesentery does not stop at its attachment along the back of the abdominal cavity; the two layers spread apart and follow around the walls in opposite directions, forming a lining for the entire cavity. Inflammation of the peritoneum gives rise to the dangerous condition known as peritonitis.[1]

Anatomically there are no lines of division in the small intestine, but it has been arbitrarily divided into three portions, duodenum, jejunum, and ileum. The duodenum consists of the first foot of the small intestine

[1] See appendix on medical terminology.

and is important in that the digestive fluids from the pancreas and liver are emptied there and mixed with the food.

Digestion in the Small Intestine.

Digestion in the small intestine is effected by ferments contained in the secretions from the pancreas and the glands of the intestinal walls, and is assisted by the bile from the liver. The gruel-like material from the stomach enters the duodenum and is there saturated with the alka-

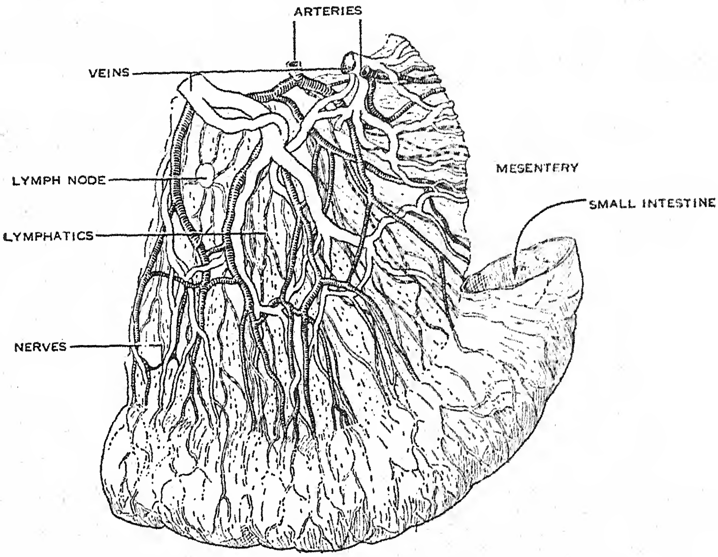


Figure 9. PORTION OF MESENTERY OF SMALL INTESTINE.

The mesentery, formed of a double layer of the peritoneum which surrounds the intestine, serves as a support for the blood vessels, nerves, and lymphatics supplied to the intestine.

line secretion of the pancreas. The pancreatic juice digests starches, proteins, and fats. Its action upon the last of these foodstuffs is aided by the emulsifying properties of the bile. A secretion resembling that of the pancreas is poured from small glands in the walls of the intestines. The secretion of the pancreas is delivered in a considerable quantity into the food material as it first enters the intestines; the intestinal secretions serve to keep it fully saturated throughout the entire passage.

The Pancreas.

The pancreas resembles a salivary gland. It lies along the lower side of the stomach in the space between that organ and the downward-

curving duodenum. Besides manufacturing a digestive secretion which is passed into the intestine, the pancreas also forms an internal secretion. The rôle that insulin plays in controlling the rate at which sugar is burned in the body will be discussed in a later section dealing with diabetes (Chapter IV).

The pancreas discharges its digestive secretion through a duct which opens into the duodenum a short distance beyond the pyloric sphincter. Bile from the liver is also discharged through this same opening. The pancreatic secretion, and also that formed in the many small glands in the walls of the intestines, is alkaline in reaction to provide the proper media for its enzymes *lipase*, *amylase,* and *trypsin*, which digest fat, starch and protein. The pancreas secretes from 500 to 800 c.c. of digestive fluid during the course of a day.

The control of the secretion from the pancreas is far less influenced by emotional factors than is that of the saliva and gastric juice. Its secretion is regulated mainly by chemical rather than nervous action. There is formed in the duodenum a substance which, when acted upon by acid from the stomach, is changed into *secretin.* Secretin is absorbed into the blood, thus reaching the pancreas where it stimulates the formation and discharge of the pancreatic fluid. The rate at which the digestive secretion is discharged into the intestine is thus regulated to correspond to the need for it.

The Liver.

The liver is the heaviest gland in the body, weighing, in the normal adult, 1.5 to 2.0 kilos (3 to 4 pounds). In certain diseases, notably heart failure, it may be distended with fluid to twice this weight. The liver is situated in the upper part of the abdominal cavity and is covered by the lower ribs on the right side. Its upper surface lies against the diaphragm. The secretion of the liver, the bile, contains no enzymes and is valuable to digestion mainly because of its emulsifying and solvent action on fats; without bile, fats are digested with difficulty or not at all. The bile is carried to the duodenum through a narrow tube which joins with the duct carrying the pancreatic fluid; both secretions empty through the same opening into the intestines. Immediately beneath the liver a branch from the bile duct leads to a small sac, the gall bladder. This sac serves as a reservoir for bile from which it is emptied as needed into the intestines. (See Figure 1.) Bile, as it is secreted by the gland cells of the liver, is orange-yellow in color and watery in consistency. During its passage through the bile duct and bladder the bile is concentrated by the removal of water; mucus is added, and the

bile becomes thick and of a dark greenish color. It has an intensely bitter taste. The greenish color and bitter taste of material passed during prolonged vomiting are due to bile-containing material regurgitated from the duodenum into the stomach. The idea, strongly held in the past, that a feeling of illness associated with digestive upset was due to disturbance of the liver, biliousness, has no basis in fact. Biliousness is wholly a misnomer.

The amount of bile formed by the liver is very scanty for so large a gland, but this secretory function is only one of many carried out by

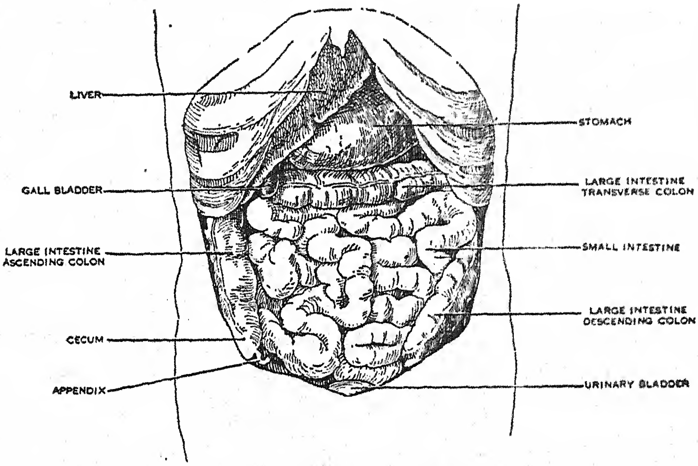


Figure 10. Abdominal Viscera.
The abdominal wall is removed to show the viscera in position.

this organ. The liver is the center for the conversion and storage of sugar, the separation of urea from amino acids, the removal of toxic materials from the blood, the production of clotting material for the blood, and other equally important activities. Life—even digestion—can continue without the formation of bile, but not without the liver; it is one of the vital organs; life lasts only a short time after its removal.

The flow of blood through the liver is peculiarly adapted to the detoxifying and storage functions of this organ. In other parts of the body the blood supplied to an organ from the arteries passes through the capillaries and into the veins which carry it directly back to the heart. In the liver the blood follows a different course; the arrangement is known as the portal circulation. Blood flowing through the

capillaries of the intestines, carrying away the products of digestion, is collected into veins, but these veins do not go directly to the heart. Instead they go to the liver where the blood is passed through a second set of capillaries. Only after it has passed through the liver and has been acted upon by the liver cells, is this blood carried to the heart.

Because of its enormous supply of blood and its distensible structure, the liver acts as an elastic reservoir to regulate the return of blood and prevent overdistention of the heart.

Gall Stones.

Although the digestive function of bile is of subordinate importance, nevertheless the secretion of bile is subject to more disturbance than is that of any other digestive fluid. Partial or complete obstruction of the duct leading from the gall bladder to the duodenum is a frequent type of malfunction; it may result from gall stones or from inflammation with swelling of the duct.

Gall stones are concretions resembling pebbles; they are made up of bile ingredients and are formed in the gall bladder. So long as the stones remain in the bladder they occasion no disturbance, but their passage into the narrow bile duct is accompanied by violent pains, biliary colic. The pains come in paroxysms and are felt most severely over the liver but radiate also to the right side of the back. The stones obstruct the flow of bile. If they succeed in passing into the duodenum, the pain and obstruction are relieved. Frequently, however, it is necessary to resort to surgery, for there is no medicinal substance that will remedy gall stones. The gall bladder, since it is not an essential organ, is then usually removed; its removal does away with all possibility of further formation of the stones.

Stagnation of the bile, due to incomplete emptying of the gall bladder, is a factor in causing stones; so also is infection of the gall bladder. Stones are most common in elderly people who have led sedentary lives, and more prevalent among women than men.

Jaundice.

When the flow of bile is interrupted the digestion of fat becomes imperfect; the stools are colored a dull gray by the undigested fat. Obstruction to the flow of bile does not suppress its secretion; the bile, unable to escape into the intestines, seeps into the blood. It is thus carried to all the tissues of the body, giving rise to the condition known

as jaundice; the whites of the eyes, the skin, sweat and urine all show a yellow color.

Obstruction to the bile duct is not the only cause of jaundice. It occurs in more than half of all infants during the first week of birth; usually the jaundice has no serious significance and is believed to arise, not from disease, but from the burden suddenly thrown upon the liver which up to this time has had little work to perform. Jaundice also occurs as the result of injury to the liver cells from disease or poisoning. There is a widely prevalent infectious variety occurring mainly among young individuals. The disease starts with gastric disturbance and some fever; jaundice develops and lasts for a week or ten days; there are rarely any serious consequences. The organism responsible for the disease has not yet been discovered. There is also a much rarer but more serious form of infectious jaundice, known as Weil's disease, which is caused by a parasite carried by rats and passed in their urine. Human beings acquire the disease from contaminated food. In the still more serious yellow fever, transmitted by a tropical mosquito, the injury to the liver gives the intense jaundice from which the disease receives its name. The poisonous action of certain arsenical compounds, phosphorus, chloroform, and some coal tar derivatives like trinitrotoluol (TNT), is in part exercised upon the liver and is followed by jaundice.

Absorption in the Small Intestine.

The absorption of digested food material takes place almost entirely from the small intestine. Much water, but little else, is absorbed from the large intestine. The absorptive surface of the small intestine is greatly increased by the moss-like roughness of the membrane which lines the tube. The products of protein and carbohydrate digestion pass through the inner walls of the small intestine and enter the blood flowing through the vessels beneath the surface. The products of the digestion of fats also pass into the walls of the small intestine, but not directly into the blood; they are first recombined into fat. Part of this fat passes into the blood and part into the lymph, a fluid which is held in a system of vessels distinct from those carrying the blood but emptying into a large vein in the chest. (See Chapter VII.) Thus the lymph, with its burden of fat, enters the blood stream without having passed through the liver. The subsequent utilization of the digested food materials is considered in Chapter IV.

Movements of the Small Intestine.

The walls of the intestine contain muscles which effect the movements necessary to mix the food which is being digested and pass it along gradually toward the large intestine. Food leaving the stomach collects in the duodenum until this part of the intestine is slightly distended; then the muscle in the wall constricts, forming a ring which nearly closes off the duodenum behind the mass of food. This ring, by progressive constriction and relaxation of the muscle, travels down the intestine as a peristaltic wave, pushing the food ahead of it. The action is similar to the "milking" of a rubber tube by squeezing it with the fingers and drawing them along the surface. Having forced the food some distance into the intestine, the initial wave fades away and is replaced by closely spaced rings of contraction with relaxed areas between them; these constrictions, without traveling forward, relax and new constrictions form midway between. Thus the food is divided into small segments and new surfaces are constantly formed for exposure to the digestive juices and to the intestinal wall for absorption. At the same time short peristaltic waves move the food mass forward, carrying it slowly throughout the entire length of the intestine.

Only a very small percentage of the digestible material in food escapes the action of the small intestine; more than 95 per cent of all the digestible material in the food is absorbed by all healthy persons. The material that reaches the large intestine is liquid in consistency; it contains much water and indigestible material; it is essentially semiliquid feces, which await merely the extraction of its water in the large intestine, to be evacuated from the body.

Large Intestine.

The large intestine commences at the lower right quadrant of the abdomen; in its five and a half feet of length it ascends on the right side of the abdomen, crosses to the left and descends; at the bottom it curves in an S-shaped spiral bend, the sigmoid flexure, and terminates in a slightly distended portion known as the rectum, which opens to the outside through the anus. The anus is, except during movement of the bowels, defecation, and the passage of gas, flatus, kept closed by a sphincter muscle.

The first few inches of the large intestine are in the form of a blind pouch, called the cecum; and the remainder, the colon, is further named, according to its direction, the ascending, transverse and descending colon. (See Figure 1.) The small intestine empties through

a valve into the side of the cecum; from the bottom of the cecum there extends the vermiform appendix.

Material from the small intestine begins to enter the large intestine two to three hours after a meal; as it collects in the cecum it is slowly pushed upward into the colon by muscular contraction. The movements of the large intestine are much more sluggish than those of the small intestine. The material normally takes ten to twenty hours to pass through the total length of five and one-half feet. During the passage most of the water is removed and the mass is reduced to a semi-solid state. This fecal matter is made up only in part of indigestible material taken with the diet; it consists also of dead bacteria from the large intestine and pieces of the inner coating of the intestine which have scraped off. The feces, even when well formed or unusually hard, contain more water than solids.

Defecation.

As the lower end of the descending colon and sigmoid flexure fill with feces, some is forced into the rectum by the peristaltic movements. The presence of material in the rectum, whether feces or a fluid introduced from the outside as an enema, initiates a reflex action which results in a wave of contraction that spreads over the whole of the colon, carrying material rapidly and forcibly toward the rectum. Unless a voluntary effort is made to keep the sphincter of the anus closed, the passage is forced open and the material is ejected. This involuntary type of defecation takes place in early infancy, during unconsciousness, and occasionally during intense emotional excitement. Usually, however, the act is under voluntary control that is acquired by experience, training, in childhood. The filling of the rectum and the onrush of material from the colon give rise to sensations which are felt as a desire to defecate. The act is then inhibited or aided voluntarily. In inhibiting defecation the sphincter is held tightly closed in spite of the pressure and discomfort experienced. In aiding defecation the sphincter is voluntarily relaxed; the diaphragm is pressed downward on the abdominal contents by a forced effort at expiration with the windpipe closed, straining. The contractions of the colon which initiate the act of defecation by filling the rectum may, by practice, be habituated to occur at some definite time during the day, thus giving regularity to bowel movement—a point of great importance in the prevention of constipation.

Bacteria of the Large Intestine.

The material leaving the stomach normally contains few bacteria, for the acid gastric juice possesses considerable antiseptic properties. Some organisms, however, survive the passage, as is evident from the occurrence of such infections of the intestines as typhoid fever, cholera and bacillary dysentery. It is evident also from the fact that although babies are born with their intestines free of bacteria they acquire, within a few days, a well-established growth in the large intestine. So regular an inhabitant of the large intestine is one particular type of bacterium that it is named the colon bacillus. It produces no disease and only occasionally causes infection in wounds. Its presence in food or water always indicates contamination by human feces.

The bacterial action in the large intestine ordinarily causes no disturbance of health; it is a normal condition. When the diet contains proteins which are difficult to digest, and which therefore reach the large intestine, the action of certain putrefactive bacteria on these proteins is attended with excessive gas formation. The flatulence which follows the eating of beans or other vegetables high in protein is produced in this manner. Cultures of bacteria, such as the acidophilous organism, are sometimes taken, usually in specially prepared milk, in order to establish a non-putrefactive strain of organisms in the large intestine.

The accumulation of gas in the intestines may occur from other causes than bacterial action. Air that is swallowed, or gas that arises from fermentation in the stomach, may pass into the intestine. During severe emotional upsets, following surgical operation, in acute infections such as pneumonia and peritonitis, and also in heart failure, gas may develop in the gut as a result of the extreme relaxation, lack of tonus, of the muscles of the intestines. The gas that then fills the intestines and gives rise to "gas pains" and severe distention of the abdomen (tympanites) is believed to come from the blood by diffusion of the gases normally carried by this fluid.

It was formerly thought that the bacteria in the large intestine produced waste products which, after their absorption into the body, were detrimental to the general health. Much was said about so-called auto-intoxication. It is possible for such a condition to occur, but it is probably very rare. Interest has now turned from auto-intoxication as a source of ill health to chronic infection of the tonsils and pus pockets about the teeth. The headache and other effects of constipation are not due to absorption of injurious material from the large intestine.

Constipation.

Since material normally passes through the small intestine in three to six hours and through the large intestine in from ten to twenty hours, most individuals defecate once each day. Constipation is a condition in which the discharge of material is delayed. The usual cause for the delay is a retardation in the rate at which material is passed through the intestines. Because of the relative amounts of time consumed in passage through the small and large intestine, the latter is chiefly responsible for constipation.

Causes of Constipation.

The greatest cause of constipation is improper diet. It is the presence of material in the intestines which stimulates movement. The feces of an infant fed wholly on milk, which has no indigestible residue, consist mainly of secretions of the alimentary tract and bacteria. Water from the milk serves to form the bulk that stimulates the intestinal movement; the feces are yellow, soft and formless. With change to a diet of solid foods the feces darken in color and become more solid. With curtailment of milk and its bulk of fluid, the material that stimulates intestinal movement is the indigestible residue of foods such as fruit and vegetables.

An herbivorous animal will suffer severely from constipation if it is deprived of the bulky cellulose which normally excites the movements of its intestines; even carnivorous animals may become constipated if fed wholly upon such completely digestible materials as eggs and meat. The household dog and cat supplement their diet either with bones or vegetable material to supply bulk for feces. Many adults of sedentary habits, whose food and liquid intake is below that to which their intestines were habituated in the growing and more active period of their lives, eat a rich diet consisting largely of absorbable material such as milk, eggs, meat, sugar and starch; although their intestines may be normal, the stimulus to movement is lacking; they suffer from constipation. By adding to their diet foods which are partially undigestible, they may relieve their constipation. Bran is sometimes used to furnish bulk to an otherwise highly digestible diet, but it may irritate the digestive tracts of some individuals. The main objection to bran—and the same applies to all especially prepared bulk-supplying substances such as agar, psyllium seeds, etc.—is that their use indicates a diet containing an insufficient supply of fruit and green vegetables which, in addition to furnishing bulk, supply needed mineral matter

and vitamins. But it must be remembered that an excess of salads and vegetables may irritate the stomach and intestines; stomach-ache and diarrhea are common as the result of overindulgence in lettuce, tomatoes and green corn.

Lack of water intake may lead to constipation; an excessive amount of water is then withdrawn from the material in the large intestine which shrinks in size so that it no longer affords the necessary stimulus to intestinal movement. Contrary to often repeated rules, no exact figure can be set for the minimum amount of water to supply adequately the daily requirements; such so-called rules of hygiene are harmful rather than beneficial, for they often give false confidence which leads to disregard of the actual needs of the body. The amount of water discharged from the body as sweat and urine is highly variable; the intake must supply the loss, and no rule that states a definite number of glasses of water a day can anticipate the variations. Water deficiency often occurs in the summer time because of profuse sweating, even though what appear to be especially large quantities of water are taken. A fair index of water requirements for those who need such an aid is to be found in the color of the urine. In health, approximately the same amount of coloring matter is excreted daily through the kidneys, giving the urine a yellowish color. A dark yellow color[1] of the urine, such as may occur in the summer time with profuse sweating, indicates concentration of the urine and a need for greater fluid intake; light straw color of the urine usually signifies a normal intake of water; very light-colored urine follows from large amounts of water, but it may occur also from other conditions such as nervousness, and so fails as a reliable index. Tea, coffee, bouillon, fruit juice and other beverages are, in regard to fluid intake, to be considered as water.

Habituation of the intestinal movement to a definite time for defecation is important for the prevention of constipation. Lack of attention to the regularity may condition the intestine not to act. Similarly, change in the daily routine, as during a train or boat trip or a vacation, may cause a break in the habit of regular evacuation which is followed by a period of constipation.

Constipation and Cathartics.

Constipation is due in some cases to a disturbance in the excitability of the muscle of the intestines. In a disease condition, such as appendi-

[1] The urine and also the feces may occasionally be colored by pigments from the food, such as the red from beets which is sometimes, on passage, mistaken for blood.

citis, the excitability may be increased at one point so that the muscle constricts in a spasm and so delays the passage of material. Far more commonly, however, constipation, particularly chronic constipation, is due to a decreased excitability of the intestines so that they do not move to a normal extent when stimulated by bulky material. This type of constipation may occasionally result from lack of vitamins in the diet and from the general debility of prolonged disease, but far more frequently it is caused by taking drugs intended to correct constipation.

Laxatives and cathartic substances—the difference is one of degree only—may be divided into three classes: (1) mineral oils, which act mainly by lubricating the intestines and thus allowing material to pass more readily; (2) saline cathartics, such as magnesium sulphate, and sodium citrate or tartrate, and the various "mineral waters," which cause a profuse flow of water from the blood into the intestines, and give a wet and bulky mass that stimulates by its volume; and (3) drugs which promote the excitability of the intestines either by irritating the walls or by rendering the nerves to the intestines more sensitive. Thus castor oil is a physic by virtue of the fact that one of the fatty acids liberated during its digestion is irritating to the walls of the small intestine, increasing motility; senna, cascara, aloes and phenolphthalein (one of the drugs most commonly used in proprietary laxatives) promote movement of the large intestine. Habitual use of the drug type of cathartic leads eventually to chronic constipation. The intestines are at first excited to perform their movements energetically, but habituation decreases their excitability. Consequently, an increased amount of the drug must be taken in order to promote what should be a normal activity. If we may judge from the money expended in advertising laxatives, America is indeed a constipated nation. Unfortunately, many of the substances offered for general sale are habit-forming cathartics. The advertisements do not indicate the harmful nature, but dwell rather upon the character of the confection mixed with the drug. Repeated sales to the same persons, and not occasional purchases, pay for this advertising.

Enemas, in which the rectum and lower part of the colon are distended with water, are harmless as occasional measures to overcome constipation that is not relieved by dietary measures; but habitual use of enemas is to be as strongly condemned, and for the same reason, as the use of drug cathartics.

Cathartics are prescribed far less commonly by physicians today than in former times, but they are still widely used in medication by the

public, not only for chronic constipation, but in the treatment of head colds and digestive disturbances of all sorts. Appendicitis frequently has as its symptoms abdominal pain, constipation and digestive disturbances; the use of a cathartic under such conditions is fraught with the grave danger of rupture of the appendix.

Effects of Constipation.

Persons suffering from chronic constipation may have no ill feeling even though defecation occurs only at intervals of four or five days. In the condition of congenital dilation of the large intestine, fecal material may be retained for a week or more without marked discomfort. But in the person whose habits are normal, constipation causes an uncomfortable feeling of fullness and distress, although health is rarely affected adversely unless the period of retention is very long. Although there is little evidence to support the belief, the idea that constipation is associated with the absorption of poisonous waste from the retained material is firmly rooted in the minds of most individuals. In reality, the discomfort of constipation arises from mechanical and not from chemical causes. The feeling of well-being immediately after a satisfactory evacuation is due to the relief from pressure and the removal of nervous irritation and not to the sudden cessation of poisoning. Relief from "poisoning" would not occur at the moment absorption of the poison ceased; that which had been absorbed would continue to act until it had been destroyed or eliminated. A man who is drunk does not become instantly sober when he vomits.

Although the delayed intestinal movement which causes constipation is mainly in the colon, the mechanical and nervous irritations which arise from the local disturbance affect the entire digestive tract. For purposes of description the tract is divided into various portions, such as the esophagus, stomach and intestines, but from the aspect of function these divisions are artificial. The digestive tract operates as an entire structure with nerve connections throughout. A disturbance in the function of any part thus affects the function of all other parts. Inflammation of the appendix may cause both constipation and vomiting, although neither of these disturbances is centered in the appendix. Similarly the lack of motility in the large intestine may reflexly interfere with the action of the stomach and may cause the mouth and tongue to become "furred." Constipation and the disturbances that may accompany it are primarily indications, symptoms, that the intestines are moving sluggishly. The alimentary tract cannot perform its func-

tions effectively unless the layers of muscle in the intestines are normally active and the proper bulk of material is supplied to stimulate movement. It is not the retention of material itself which is harmful, but rather the factors which cause the retention. Although constipation is not as serious as is commonly believed, nevertheless it is an abnormal state, a symptom of bodily derangement and of malfunction of the alimentary tract. Every effort should therefore be made to maintain, by habit and diet, regular evacuation.

The straining associated with constipation is a factor in causing hemorrhoids or piles which are discussed in Chapter VI.

Diarrhea.

Diarrhea is the term applied to unusually frequent passage from the bowels of material more or less fluid in character. Diarrhea results from an abnormally rapid passage of material through the intestines; the large intestine is not given sufficient time to extract the water. The increased motility may be caused by irritation from foods with a large undigestible residue, from chemical substances, and from bacterial infection; it may also result from nervous and emotional disturbances. The motility of the intestines is influenced by the emotional state; excitement or fear may give rise to the desire for defecation and may be followed by diarrhea. In some persons rapid movement of the intestines is associated with a rumbling sound designated by the onomatopoetic term, borborygmus; as mild an emotion as embarrassment may increase the frequency of the sound.

Diarrhea involves a loss of water from the body, and much of the prostration incident to prolonged diarrhea is due to this dehydration. Many persons use indiscriminately the words diarrhea and dysentery; the latter applies properly only to a severe form of diarrhea in which the stools contain blood.

Appendicitis.

The most common serious intestinal disorder is acute appendicitis or inflammation of the vermiform appendix. The appendix is a tubular projection about the size of the little finger, extending from the bottom of the cecum. Its outer end is closed; its central passage opens into the cecum. The walls of the appendix secrete a small amount of greenish yellow pungent fluid which has no function in digestion. The appendix itself is a useless structure, an evolutionary remnant from herbivorous animals in whom the appendix is large and useful.

Appendicitis is mainly a disease of young people, occurring usually, but by no means always, before the thirtieth year. It results from an infection of the appendix, generally with bacteria normally found in the large intestine. Formerly it was believed that the infection followed injury by some foreign body, such as a fruit seed, that had found its way into the appendix; it is now known that such is rarely the case. The susceptibility of the appendix to infection is explained on the basis of its anatomical peculiarities; its narrow blind passage is readily obstructed and its closely bound blood vessels are shut off when swelling occurs. The surface of other parts of the alimentary tract is no doubt frequently scratched but heals quickly. The appendix when similarly injured is, because of its natural weakness, prone to infection. The tendency is further exaggerated by individual abnormalities in the structure of the appendix such as unusual length or bent position.

Acute appendicitis is characterized by pain and tenderness in the lower right side of the abdomen. The pain may appear first near the middle of the abdomen but soon moves to the right side. Sometimes it comes on suddenly and is extremely severe; more often it develops slowly after a short period of general discomfort. Nausea and vomiting usually occur. The treatment of appendicitis is the prompt surgical removal of the appendix. Delay in operation may lead to fatal outcome, for if the inflammation increases the appendix may rupture and the infected intestinal contents be poured out into the abdominal cavity, giving rise to peritonitis. When it is impossible to obtain prompt medical aid the person suspected of having appendicitis should be kept perfectly quiet in bed. Either cold or hot applications over the lower right side of the abdomen may give some relief. No food should be given and, above all, never a physic.

Hernia.

The protrusion of some organ of the body through the walls of the compartment in which it is normally contained is called hernia. Thus there can be hernia of the brain, when it bulges through an opening in a fractured or imperfectly formed skull; hernia of the liver into the chest cavity through a tear in the diaphragm, or hernia of the intestines with extrusion, when a rupture has occurred in the muscles of the abdominal wall. The last type is far more frequent than any other.

The abdominal organs are contained in a cavity which makes up the greater part of the trunk of the body. This compartment is

bounded above by the muscular diaphragm, which stretches across the body at the level of the lower ribs; at the bottom by the bones and muscles of the pelvis; behind by the spine and muscles of the back; and laterally and in front by the muscular abdominal walls. In three places the wall of the abdomen is weak: at the umbilicus or navel; at the exit of the blood vessels which supply the legs; and around the spermatic cords of the male as they leave the abdomen to enter the scrotum. When hernia of the abdominal contents occurs, it is nearly always in one of these three localities, and is designated respectively as umbilical, femoral, or inguinal hernia.

In the male the testicles are developed in the abdominal cavity and remain there until a short time before birth. From this position they descend into the scrotum. In their descent they pass through the layers of muscle on the front of the abdomen. The openings made in the muscle are just above the bones of the pelvis which run across the base of the abdomen. The inner opening on each side is at some distance from the mid-line of the abdomen; the outer opening only a short distance from the mid-line. These openings are called the inguinal rings. In passing from the inner to the outer rings the testicles go between the layers of muscle, thus forming passages known as the inguinal canals. As they descend, the testicles push ahead of them the peritoneum of the abdominal cavity; behind each of them extends the tube, the vas deferens or spermatic cord, through which the spermatozoa pass.

The inguinal rings normally close tightly over the structures which extend through them, and the peritoneum is thus held firmly about the spermatic cords so that the intestines cannot extend along their course. In some cases, however, the peritoneum is not held firmly to the cords. In such cases the inguinal rings may become stretched as a result of the pressure of the intestines against them during muscular exertion, and a space is opened into which the intestines pass. The hernia thus formed may extend no further than the canal or it may extend into the scrotum and distend it with loops of intestine.

Hernia may be recognized by the bulging of the abdominal wall over the point of extrusion. Gentle pressure usually serves to force the intestine back into its normal compartment; technically this procedure is called reducing the hernia, but on removing the pressure the hernia recurs. In some hernias the extruded organ forms adhesions to the wall of the canal and becomes reducible only by operation.

It is now generally believed that hernia develops only when there

is a congenital imperfection of the abdominal wall. Repeated muscular effort, as in lifting heavy objects, while not the primary cause of hernia, increases the likelihood of the intestinal protrusion in those who are susceptible. In lifting, particularly if the body is in the upright position, the abdominal muscles are strongly contracted; this increases the pressure within the abdominal cavity and tends to extrude the intestines. Hernia is more liable to follow repeated strain than occasional muscular acts of exceptional violence; the strain leads to a gradual stretching of the congenitally weak tendinous rings about the canals.

Untreated hernia is a severe physical handicap and at times an actual danger from the possibility of "strangulation." A hernia is said to be strangulated when the extruded intestine is packed so tightly in the opening from the abdomen that the flow of blood is shut off by the pressure. Strangulated hernia is a grave condition, for unless the blood supply is restored by operative reduction within a short time, the extruded intestine dies and the outcome may be fatal.

There are two treatments of hernia: first, a surgical operation to repair the enlarged opening through which the intestines are extruding; and, second, a truss to hold the intestines in place. A truss is usually in the form of a flat metal spring which encircles the body and bears on a pad placed over the hernia; the force of the spring is sufficient to counteract the extruding force exerted by the intestine. The hernia of an infant held in place by a truss may heal, but a truss does not cure hernia in an adult; to hold the intestine in place, it must be worn continually.

Animal Parasites of the Digestive Tract.

On both its outer and inner surfaces the body may be host to a variety of animal parasites; fleas may live and lice may thrive on the skin, while "worms" of various types may infest the intestines. Skin parasites make their presence known immediately, but an individual may be unaware of the parasitic messmates which flourish within the body. Most intestinal worms, probably as the result of long evolutionary association and adjustment, live in reasonable harmony with their hosts, giving rise to little ill health, an advantage to the worms since death to the host is death to the parasite. A few, assumed to be more recent acquisitions, cause ill health, occasionally even death; and one in particular, the hookworm, is responsible for the low vitality, stunted

growth, and lack of efficiency of many millions of inhabitants of warm regions.

Prevention of infection by the intestinal parasites can be accomplished only by knowledge of the manner in which they are acquired. The parasites have ingenious methods of propagation for their transfer to new hosts, without which they would rapidly die out. Many parasites during one phase of their life cycle live in some animal, an intermediary host, other than the final host which the adult worm infests. Nearly all, however, discharge their eggs in the excreta of this host as the first step toward the transfer to new hosts. Therefore, regardless of all details of the complicated life cycle of the parasites, the fact remains that worm infestation can occur only as the result of crude neglect of sanitation in disposing of human excrement.

The parasitic intestinal worms infesting man belong to two great groups, the flatworms and the roundworms, which are in turn divided into a number of varieties.

- Flatworms
  1. Flukes
  2. Tapeworms
     - Pork tapeworm
     - Beef tapeworm
     - Fish tapeworm
     - Echinococcus
- Roundworms
  1. Ascaris
  2. Trichina
  3. Hookworm

Infestation by flukes occurs mainly in the Far East, only occasionally in the southern parts of the United States. There are many species of these small worms and most center their action in parts of the body other than the intestines. Thus there are flukes that infest the liver, others the lungs, and still others the abdominal veins. The symptoms that develop depend upon the organ involved. The eggs of the flukes leave the body through the feces or the urine. The larval worms may attach themselves to intermediate hosts in fresh water. Thus the intestinal flukes may contaminate water-grown vegetables, such as cress, making such foods dangerous to eat in the raw state in infested regions. Lung flukes use as their intermediate hosts fresh-water crabs, and the blood flukes, snails. The small worms, escaping from the snails, swim about in the fresh water; they infest man by penetrating his skin when he bathes or wades in the stream that harbors them.

Tapeworms.

The hog is the intermediary host for the pork tapeworm, and this parasite is found throughout the world wherever pork is consumed,

but only among those individuals who eat the meat insufficiently cooked. The adult worm lives in the upper part of the small intestine of man, attached to the wall by means of the hooks and suckers on its minute head. Immediately behind the head, small flat segments are formed which remain attached as succeeding segments are produced, so that a series is formed resembling a tape, from which the worm gets its name. A length of six to ten feet or more may be reached. Although the head of the worm is only about 1/25 of an inch in length, and the segments as first formed are even smaller, they develop as they are moved along until they become a third of an inch wide and two-thirds long. The segments are made up largely of sex organs filled with eggs; as they attain maturity they break off in groups of four to six and are passed out in the feces.

The eggs reach the hog on grass or other vegetables or in water contaminated with the feces. The enormous chance of failure for any one egg to reach a host in this method of propagation is partially compensated by the prodigious number of eggs produced by each adult parasite; for many years a tapeworm in a man's intestine will produce several thousand eggs each day.

In the hog the behavior of the parasite is quite different from that in man. The swallowed eggs hatch out in the digestive tract into minute larval worms which penetrate the walls of the intestine and enter the blood in which they are carried until they finally lodge in the muscle of various parts of the body. Here they incrust themselves with a layer of tissue and remain dormant. The muscle of the pig thus infested is called "measly pork" and will not, if detected, pass government meat inspection.

Thorough cooking kills the larval worms and renders the meat safe for human consumption. If the meat is eaten rare or raw the living larvae reach the intestine; there they become active. The head is attached to the intestinal wall; growth proceeds, segments are formed, and eggs develop and are passed out with the feces.

The pork tapeworm usually causes no symptoms in an adult; the presence of the worm is ordinarily discovered only when a group of segments are observed in the feces. In children there may be some gastrointestinal irritation.

The beef tapeworm is in all essentials, except its size and intermediate host, similar to the pork tapeworm. The worm may develop some 2000 segments and grow to a length of twelve to thirty feet; the segments are expelled singly instead of in groups. The worm is found wherever beef is eaten. Infestation can be prevented by eating the meat

only after it has been well cooked. Infestation could be eliminated—and this applies as well to nearly all intestinal parasites—if reasonable sanitation methods were followed in the disposal of human feces.

In contrast to the fairly harmless pork and beef tapeworms, the fish tapeworm not only causes gastrointestinal disturbances, but leads to a severe form of anemia. It is one of the more dangerous intestinal parasites. Infestation is now becoming increasingly prevalent about the fresh-water lakes of the eastern half of the United States. The worm, which is one of the largest, develops as many as 4000 segments and reaches a length of thirty feet. It can infest the dog, cat and fox as well as man, and requires two intermediate hosts for its development, a fresh-water crustacean and a fresh-water fish. Human beings become infected by eating insufficiently cooked fish; and in turn human beings play their part in the spread of the parasite by pollution of lakes with sewage.

The echinococcus tapeworm is the smallest of those of any importance in human infestation; when full grown it measures less than a half inch in length. For this worm man occupies the position, not of a primary but of an intermediate host, a situation which he shares with cattle, sheep, goats, swine and horses. The adult worm lives in the intestines of the dog. The eggs pass in the feces and reach man through contaminated food and water. They hatch in the digestive tract; the larval worms penetrate the intestinal wall, enter the blood and are carried to various organs, the lungs, the heart and the brain, but especially the liver. Wherever they locate, the further development of the parasite results in what is known as a hydatid cyst, a gelatinous mass that may reach a diameter of six or more inches. Surgery is the only known method of treatment.

The treatment of other forms of tapeworm infestation is largely medical and aims to detach the head of the worm from the intestine. Treatment is given only after eggs have been found in the feces and identified by microscopic examination. Drugs for the removal of tapeworms are poisons to man as well as to the worm, and therefore should be administered only by a physician.

Ascaris.

The ascaris is somewhat similar in shape and size to a large earthworm. No intermediate host is required in its development. The eggs pass in the feces of the infested individual and reach the new host in contaminated food or water. In regions where the ascaris is common there is special danger in the use of raw vegetables, like lettuce, celery

and radishes, grown in soil fertilized with human excrement. The ingested eggs hatch in the small intestine but the larval worms do not remain there; instead they go through a period of migration, after which they return to the digestive tract. The minute larvae burrow through the walls of the intestines and are carried to the heart and from there to the lungs; here they pierce the walls of the air sacs and, after a period of growth, crawl up the windpipe, enter the esophagus, pass through the stomach, and so reach the intestines. Usually infestation by ascaris causes no serious illness.

Trichina.

This worm, which measures at most an eighth of an inch in length, is not primarily a parasite of man, but of rats; nevertheless, entire human families are occasionally infested, and with serious consequences. The adult worms live only temporarily in the intestine; they mate and then the female burrows into the intestinal wall and brings forth young worms which enter the blood vessels and are carried throughout the body. Reaching the muscles they burrow into them and incrust themselves with a shell; they may live in this dormant stage for many years. In rats, transfer to a new host depends upon cannibalism; when an infested rat is eaten by another, the trichinae in the muscle, liberated by digestion, go through their brief reproductive cycle followed by the migration of the young worm into the muscle of the new host. Hogs often feed on rats or the infected offal of other hogs, and are thereby infected. Man acquires the parasite by eating raw or undercooked pork.

Usually no serious effects are noticed immediately after eating the infected meat, but only after a lapse of ten days or two weeks, at which time the migration of young worms commences. There is severe muscular pain and disability, with some fever. The disease is occasionally complicated by pneumonia and death may result. There is no effective treatment for the disease, but the infestation can be prevented by thoroughly cooking all pork products prior to consumption. Meat inspection does not reveal the presence of the trichinae.

Hookworm.

Hookworms[1] are one-quarter to one-half inch in length, curved or hooked in shape, and equipped with sharp teeth or cutting plates. The

[1] There are two varieties, the "Old World" and the "New World" hookworm: *Ankylostoma duodenale* and *Necator americanus*.

adult worms live in the small intestine attached to the wall by their mouths; they may persist there for five to six years. The worms get their nourishment from the blood which they suck. Anemia is an outstanding feature of the disease. Children affected are stunted in growth; adults become emaciated. There is a disinclination for physical and mental exertion; the affliction is popularly spoken of as the "lazy disease." The expression of the face is dull and blank, the eyes are vacant and staring. Sometimes the sense of taste is perverted; a craving to eat dirt, or clay, or plaster develops.

The adult female worm discharges eggs which pass out with the fecal matter. When deposited on warm, moist soil the eggs hatch in a day or two; the larval worms live on fecal matter until they have molted twice, when they become infective. From the soil the larvae invade man, usually by burrowing through the skin of the feet. The passage of the worm is followed by a local irritation called "ground itch." Once through the skin, the worms are carried in the blood to the heart and from there to the lungs, from which they burrow their way into the air sacs. Their further progress is essentially the same as that of the ascaris; they crawl up the windpipe and are swallowed. In the intestines they go through two more molts before reaching the adult size. A period of three to four weeks is covered from the time of entry through the skin until the eggs of the newly established worms appear in the feces.

The larval worms living in the soil cannot survive prolonged freezing, a fact which accounts for the geographic distribution and limitation of the disease. The area of infection belts the world in a zone about 66° wide, extending approximately from 36° S. to 30° N. Nearly 1,000,000,000 persons live in this area. Infestation with hookworm in some tropical and semi-tropical countries presents an economic and social problem of enormous magnitude.

The control of hookworm infection is simple; it involves only the prevention of soil pollution and the wearing of shoes. Even these elementary sanitary measures are difficult to enforce on poor and uneducated people, stunted in mind and will by the parasites which their unsanitary habits foster.

Hookworm disease is diagnosed by finding the eggs in the fecal matter; it is treated by expelling the worms from the intestines with the use of thymol, carbon tetrachloride, or other drugs. Shoes must be worn out-of-doors at all times after treatment; otherwise reinfection

may occur. Persons who are cured of hookworm disease soon show a marked increase in industry and initiative.

Even in cold climates the hookworm may persist in mines and tunnels where the ground does not freeze. In such localities the soil pollution is often extensive, and the contact of the workers with the ground is intimate. A disease long called "miners' anemia" is now known to be hookworm disease. It is likely to develop in any subterranean work unless sanitary precautions are maintained.

Cats and dogs may be infested with a variety of hookworm. Although it cannot reach the intestinal tract of man, its larvae may, nevertheless, penetrate his skin on contact with polluted soil. The larvae remain beneath the skin, migrating in a tortuous course marked by an eruption and accompanied by intense itching. The disease is known as creeping eruption. It is prevalent in the southern part of the United States, especially Florida, and occurs occasionally in the northern part. The parasite can usually be killed by applying refrigerants, such as ice and salt, or dry ice, to the affected skin.

Amebic Dysentery.

The amebae, although classed as animals since they belong to the group of Protozoa, are much more elementary in structure than the parasitic worms; they consist of a single cell, a minute irregular bit of protoplasm. They send out gelatinous projections as temporary feet for moving or engulfing food. There are many different species of amebae; some are commonly found in the water of stagnant pools; others occur as harmless inhabitants of the intestinal tract of man and other animals. Only one variety is harmful to man, the so-called endameba histolytica. The ordinary types of amebae that find their way into the digestive tract with food and water subsist, if they survive, on particles of food or fecal matter. The endameba, on the contrary, attacks the intestinal wall and ingests red blood corpuscles.

In severe and active infection the amebae multiply enormously by simple division and are passed in great numbers with the feces. They are delicate and survive only a short time outside the body; hence they cannot be transmitted to new hosts. When the active state of infection subsides, some of the amebae form cysts. They incrust themselves with shell-like membranes inside of which they divide, forming two, and then four, smaller amebae. The cysts are far less delicate than the active amebae and can exist outside the body. When ingested by a

new host, the amebae are discharged from the cysts and infection results.

During the stages in which the amebae multiply rapidly in the intestines, the walls are injured; dysentery and abdominal pain occur. Frequently after this stage subsides the amebae persist for months or years, so that the disease may recur at any time; at all times the cysts are passed in the fecal matter. Persons thus affected, even when they show no symptoms of the disease, may spread it; they are carriers.

In occasional instances the amebae so erode the intestine that it becomes perforated; occasionally also they enter the blood vessels and are carried to the liver, producing there an amebic abscess.

Amebic dysentery is a prevalent disease in Egypt, India, China, and in tropical countries. It can and does occur, but with less frequency, in temperate regions. The disease is spread by the contamination of food and water with the feces of those who harbor the parasite.

Certain substances, notably emetine, an alkaloid derived from ipecac, are poisonous to the amebae and are used successfully as medicaments in ridding the intestinal tract of the parasite.

Bacterial Infection of the Digestive Tract.

There are certain diseases, caused by bacteria, which center their main action on the intestines. Of these the most important are typhoid fever, the paratyphoid fevers, bacillary dysentery and Asiatic cholera. Although each is caused by a separate organism, the mode of transmission is the same for all. The bacteria are passed from the body in the fecal matter; infection results from the use of food or water contaminated with this excrement.

In many tropical regions where sanitation is lacking, the diseases are spread largely by water pollution. Such also was the case in the United States, particularly in regard to typhoid fever, until the present century. Up to that time most city water supplies were contaminated with sewage, and typhoid fever was a widely prevalent disease. Active measures were taken to overcome this grave situation; and now, by filtration, sedimentation, and chlorination, all city water supplies are kept free from typhoid bacilli. In consequence the disease has decreased enormously in prevalence; wide epidemics no longer occur. There is, however, still danger of water-borne infection in rural districts; well water may be contaminated by the drainage from a privy or cesspool and surface water from sewage deposited or washed into it. The ap-

pearance of water is not altered by contamination with typhoid bacilli; the clear, cool water of a mountain stream may teem with the organisms from contamination by a camp or dwelling some distance up the stream. The dangers of extensive water-borne infection occur in time of floods; all rivers passing through thickly settled regions are today, as in the past, contaminated with sewage.

There have been wide outbreaks of typhoid attributed to oysters "fattened" in polluted fresh-water streams and to contaminated milk and ice cream. Under the sanitary conditions now enforced in the cities of the United States there is little likelihood of such epidemics. Today the main source of infection is from carriers engaged in handling food. A "carrier" is an individual who, without showing symptoms of the disease, nevertheless harbors the bacilli in his body and passes them in his excrement. The bacilli are carried to food on the soiled hands of the carrier. There have been carriers who, acting as cooks, were responsible for many cases of typhoid fever; some, like the notorious Typhoid Mary of New York, have been placed in institutions to prevent their spreading the disease. It is estimated that from 1 to 3 per cent of individuals recovering from typhoid fever continue to excrete the organisms for months or years. Consequently it is unwise to allow anyone who has ever had typhoid fever to handle food until their excreta have been shown by examination to be free from typhoid bacilli. There are other carriers from whom no history of typhoid fever can be obtained; they have never had the disease in recognizable form, but they nevertheless harbor the bacilli in focal infections, often in the gall bladder, and pass them in their excrement.

What is said here concerning the transmission of typhoid fever applies likewise to the other bacterial infections of the alimentary tract. The modern city dweller is, except for carriers, well safeguarded against these diseases; the traveler and camper and country dweller must provide their own protection. For them, in addition to care in avoiding contaminated water and food, protective inoculation is especially advisable. A vaccine in the form of a suspension of killed typhoid and paratyphoid bacteria injected hypodermically gives some immunity against the diseases caused by these organisms. The immunity is not absolute; the diseases may develop if the infection occurs from an unusually large number of bacteria, but the disease is then milder than it would be for the unvaccinated individual. Vaccines have also been developed to prevent bacillary dysentery and Asiatic cholera.

Typhoid Fever.

The symptoms of typhoid fever usually appear within one to two weeks after infection. As a rule they come on gradually; there is loss of appetite, headache and tiredness, but no defínte symptoms that point directly to the nature of the disease. Fever develops and the affected individual usually feels ill enough to go to bed, often with his disease mistakenly diagnosed. It is only at the beginning of the second week that small red areas, "rose spots," appear on the skin and the spleen enlarges. The disease can then usually be unmistakably diagnosed as typhoid; the diagnosis is confirmed by a blood test, the Widal test, in which a drop of blood is brought in contact with typhoid bacilli under a microscope. If the disease exists in the man from whom the blood was taken, the bacteria cease moving and gather together in clumps; if the disease is not present, the bacteria are unaffected.

During the third week the disease increases in severity; there is high fever, prostration, and sometimes delirium. It is at this time that complications may develop. Of these, perforation is one of the most serious. The bacteria act upon the mucous membrane of the small intestine and cause ulcers; one or more of the ulcers may erode through the wall of the intestine. Severe and fatal hemorrhage may also occur. Usually in the fourth week the severity of the disease subsides, unless the bacilli have spread to, and involved, other parts of the body. There is no cure for typhoid fever, but, although it is a serious disease, life can usually be saved by good medical and nursing care.

Paratyphoid Fever.

There are two slightly different bacteria that cause so-called paratyphoid fever. One is the paratyphoid bacillus A, and the other B. Infection with type A results in a disease that resembles typhoid fever but is milder and shorter. The disease that results from type B is usually marked by severe gastrointestinal disturbances, vomiting, cramps, and diarrhea.

The inoculation given primarily against typhoid fever contains, in addition to the killed typhoid bacilli, paratyphoid bacilli A and B so that protection is afforded against the disease caused by these organisms.

Bacillary Dysentery.

This disease is caused by a series of closely related bacteria included together as the Bacillary Dysentery group. The disease develops from one to seven days after infection. The symptoms usually appear sud-

denly; there is fever, abdominal pain, vomiting, and frequent bowel movements. In severe cases blood is passed. The disease shows great variation in intensity, ranging from mild diarrhea lasting only a day to violent dysentery with death.

Bacillary dysentery occurs in all parts of the world, but is more prevalent in warm countries because of lack of sanitation.

Asiatic Cholera.

Any severe disturbance of the alimentary tract associated with diarrhea and cramps is called cholera. Thus bacillary dysentery is sometimes given the name cholera nostras, mild cholera, to differentiate it from the more severe Asiatic cholera.

Cholera has been endemic in India and other countries of the East from a remote period, occasionally spreading in epidemics which have taken frightful toll of life. In the last century the disease spread to Europe and America. In 1832 Asiatic cholera was brought to Quebec in emigrant ships; from there it spread along the lines of traffic up the Great Lakes and as far west as the military posts of the upper Mississippi. In the same year it appeared in New York. In 1848 it entered the country through New Orleans and spread up the Mississippi Valley and across the continent to California. It was again introduced in emigrant ships in 1854. It appeared last in the United States in 1873. Since then, although wide epidemics have prevailed in the Near and Far East, the quarantine of immigrants has prevented the entrance of the disease into this country.

Asiatic cholera is caused by an organism which, from its shape, is known as the comma bacillus. A period of two to five days elapses between the infection and the onset of the disease. The symptoms are those of violent diarrhea, with vomiting and great weakness. So extensive is the loss of water through the incessant diarrhea and vomiting that the blood volume and tissue fluids are dangerously depleted. The thirst is intense. Within a short time the features are shrunken, the cheeks hollow, the eyeballs sunken, and the skin shriveled. Treatment by the injection of dilute salt solution into a vein has materially reduced the mortality of the disease in recent epidemics.

CHAPTER IV

FOOD, WORK AND HEAT

Fate of Foods in the Body.

The transformations which the food undergoes after being absorbed into the body are called metabolism. Metabolism may be studied from the aspect of energy liberation, and its rate estimated for any period from the work and heat produced by the body. Or it may be studied by following the changes which a particular food undergoes from the time it is absorbed into the blood until it is eliminated as waste; thus we speak of the metabolism of fats, proteins, and carbohydrates.

Metabolism of Carbohydrates.

The simple sugars, glucose, fructose and galactose, occurring as the end products of carbohydrate digestion, are absorbed into the blood in the vessels surrounding the intestines. Glucose, however, is the only one of these sugars that can be utilized by the tissues of the body; it is the only sugar found in the blood brought to them. Any sugar, other than glucose, injected into the blood experimentally is promptly eliminated through the kidneys. The blood from the intestines, as has been pointed out, flows through the liver; this organ transforms the absorbed fructose and galactose into glucose. But even when transformed, the passage of the sugar into the circulating blood, and that of the original glucose absorbed as well, are controlled to maintain a nearly uniform concentration in the blood.

The maintenance of this uniform concentration is one of the fundamental adjustments of the body; it is one of the so-called vital constants, such as the temperature of the body, the basal rate of energy expenditure, and the alkalinity of the blood, to be discussed subsequently. The regulation of the sugar concentration in the blood is such that, in spite of great fluctuations in the consumption of carbohydrates, the blood leaving the heart contains approximately 0.1 of one per cent of sugar. In health the fluctuation rarely exceeds the limits 0.08 to 0.18 of one per cent. This constancy is maintained by means of a system of regu-

lated absorption, storage, and mobilization, safeguarded by an emergency overflow.

There is a maximum rate at which sugar can be absorbed from the intestines. It is reached when approximately an ounce of carbohydrate is eaten; greater amounts are not absorbed more rapidly but only over a longer period. This regulated absorption prevents the blood flowing to the liver from being flooded with sugar following the ingestion of a large quantity of soluble carbohydrate, such as candy.

The liver is the center where sugar is stored and mobilized. This organ abstracts from the blood reaching it, any sugar in excess of the normal concentration, converts it into a starch, called glycogen, which is stored in the liver. From the blood circulating throughout the body sugar is removed and used in the vital combustion within the muscles and other tissues; the blood leaving these organs therefore contains less than the normal amount of sugar. Liver glycogen is then reconverted into sugar and the deficit in the blood is made up.

The human liver has the capacity to store 150 to 250 grams (6 to 9 ounces) of sugar. It is thus able to arrest and fix any ordinary amounts coming from the digestive tract. The intake of an especially large amount of carbohydrate, such as a pound of candy, exceeds the sugar storage capacity of the liver, and the concentration in the blood rises beyond the normal limits. The kidneys then act to get rid of the excess. Blood containing as high as 0.16 or even 0.18 of one per cent of sugar circulates through the kidneys without appreciable loss of sugar; but if the content is higher, the excess of sugar is excreted into the urine. This overflow of sugar into the urine, as a result of excessive ingestion of carbohydrates, does not often occur, for the forcing of such an excess is nauseating to most people. In certain diseases, notably diabetes, the amount of sugar which can be eaten without any passing into the urine is greatly diminished. Medical tests are carried out to determine this amount, which is called the glucose tolerance. Most normal individuals can tolerate 100 grams or more.

Following meals containing carbohydrates the sugar in the circulating blood may, for an hour or two, rise to a concentration of 0.14 to 0.16 of one per cent, but subsequently, unless disturbed by another meal, it remains constantly and uniformly at a value close to 0.1 of one per cent. If starvation persists, the small amounts of sugar necessary to maintain the essential minimum in the blood are derived from the amino acids of protein, in this case the body's own proteins. When the sugar supply is high in the body, as after meals, this fuel is burned in

preference to fat; but when the sugar supply is reduced the sugar is carefully conserved and only the minimum amount consumed. Muscular exertion is performed less efficiently when the fuel used is mainly fat; it can be performed with difficulty, or not at all, when the sugar supply is virtually exhausted. Thus a Marathon runner collapses when he has consumed all of his glycogen and nearly all of the sugar in his blood. It is increasingly the practice in athletics to provide an adequate glycogen supply for contestants prior to their competition, particularly if the effort is to be long sustained. Between-meal feeding of carbohydrate to maintain the concentration of sugar in the blood above the minimum fasting level has been found to give industrial workers greater muscular efficiency and greater freedom from fatigue and irritability.

The muscles, as well as the liver, store sugar as glycogen, but the muscle glycogen cannot be freed as sugar to maintain the concentration in the blood; it is used only in the muscle where it is deposited. This storage of glycogen, as well as the storage in the liver, is limited. There is another mode of storage which is unlimited. Carbohydrates can be converted into fat and stored in this form; the fact that sugar and starch, taken in excess of the body's needs, are fattening is a commonplace. The fat deposited in the body may be drawn on for fuel whenever the food intake falls below the needs for energy expenditure.

The rate at which sugar is mobilized from the glycogen in the liver is not entirely automatic, but is influenced to some extent by emotional states. Fear, rage, and pain cause an increase in the concentration of sugar in the blood, presumably that there may be a supply of this fuel ready for the expected muscular exertions of flight or combat. If the exertion occurs, the extra sugar is burned; but if the emotion is suffered without exertion, some of the excess sugar may pass into the urine. Sugar can frequently be found in the urine of football substitutes anxiously waiting on the side lines; but it is not found in the urine of the active players.

The combustion of sugar in the body for the conversion of chemical energy into heat and work results in the combination of the carbon of glucose with oxygen; carbon dioxide is formed and water separated. The process involves complicated chemical reactions in which lactic acid is formed as an intermediate step. It suffices for the purpose here to express the combustion in its initial and final stages only:

$$\underset{\text{(glucose)}}{C_6H_{12}O_6} + 6O_2 = 6H_2O + 6CO_2 + 4.1 \text{ kilocalories}$$

In burning a single molecule of glucose, six molecules of oxygen are used, and six of carbon dioxide are liberated. If sugar were the only fuel burned in the body, the amount of oxygen consumed and the amount of carbon dioxide produced would be equal. For the combustion of fat the amount of carbon dioxide is less than the oxygen. The ratio $\frac{CO_2 \text{ produced}}{O_2 \text{ consumed}}$ is known as the respiratory quotient, R.Q. It can be determined by actual measurements made upon a man; the value obtained indicates the proportion of carbohydrate and fat burned in the body at the time (see section on indirect calorimetry).

Insulin and Diabetes.

The combustion of sugar with the liberation of energy is dependent upon the presence of an internal secretion formed in the pancreas and known as insulin. The action of insulin is complicated, involving not only the oxidation of sugar but also the storage of glycogen in the liver; the essential fact here is that sugar cannot be burned in the body if insulin is not present. Insulin can be extracted from the pancreas of cattle and is available as a medicinal preparation for the treatment of the disease diabetes discussed below. Insulin is not effective when taken by mouth, for it is destroyed by the digestive fluid; it must be given by hypodermic injection.

When insulin is injected into the body—or discharged from the pancreas into the blood in the normal manner—sugar is burned in preference to fat. If the dose of insulin is excessive, or if an adequate supply of sugar is not available, the extensive oxidation causes a rapid decline of sugar in the blood. When the concentration falls below 0.05 or 0.06 of one per cent, symptoms of so-called insulin shock develop. The muscles become weak, convulsions and unconsciousness may develop. These symptoms can be prevented or relieved by the administration of glucose. In the commercial preparation of insulin the dosage is recorded in units; one unit is taken arbitrarily as one-third the amount necessary to produce convulsions, insulin shock, in a rabbit weighing 2 kilos. One unit is needed for the oxidation of 3 to 8 grams of carbohydrate.

The common form of diabetes, diabetes mellitus,[1] is the result of

[1] A much rarer form known as diabetes insipidus results from a disturbance of the pituitary gland; large quantities of urine are passed and there is great thirst. It does not, like diabetes mellitus, interfere with sugar metabolism and cannot be successfully treated with insulin.

profound derangement of carbohydrate metabolism. The central feature is the failure of the pancreas to secrete an adequate amount of insulin. For this reason diabetes is sometimes spoken of as hypoinsulinism. In some cases the failure is due to demonstrable disease of the pancreas; more often no such disturbance is found. The metabolism of carbohydrate is controlled not by the pancreas alone, but by a complicated interaction among the secretions of several glands of internal secretion, the pituitary and adrenals as well as the pancreas. Thus the failure of the pancreas to produce an adequate amount of insulin, or an effective insulin, may be the result of disturbances, as yet imperfectly understood, in glands other than the pancreas itself. In consequence of the disturbance the oxidation of glucose is impaired, the capacity of the liver to store glycogen is lost, and the body is forced to use fat instead of sugar.

The symptoms of diabetes develop from these disturbances. The failure of sugar storage and utilization results in a high concentration of sugar in the blood. Sugar then appears in the urine. The passage of sugar necessitates a large flow of urine and this in turn leads to intense thirst. Since food is wasted, hunger is increased, but weight is lost. The failure of sugar utilization leads to muscular weakness and fatigue. In the absence of sugar combustion, fat is burned imperfectly; the products of fat oxidation, such as ketones and other substances, accumulate in the blood. In severe and untreated diabetes, unconsciousness may develop and death occur.

Before the commercial availability of insulin, the only measure for controlling the disease was through diet. In many cases of diabetes of moderate severity a diet free from carbohydrates relieves the symptoms of the disease; with improvement, small amounts of starch and sugar may finally be tolerated and utilized.

In severe cases of diabetes life is prolonged, but not saved, by diet alone. Daily injections of insulin serve to supply the deficiency from the pancreas and to maintain a nearly normal carbohydrate metabolism. The insulin is not, however, a cure in the true sense of the word; its use must usually be continued throughout life.

The causes of diabetes are not known. In some instances there appears to be an hereditary tendency; but in others it cannot be found. The eating of large quantities of sugar and candy is popularly assumed to be a cause, but there is little evidence to support this belief except the fact that before the disease develops an increase in weight usually occurs. Overweight is considered to be a predisposing cause of diabetes;

but whether the overweight incites the disease, or is itself an indication of a more fundamental disturbance of metabolism leading to diabetes, is not known. The disease may occur at any time of life, even infancy, but is most common after fifty.

Hyperinsulinism.

In complete contrast to diabetes (hypoinsulinism) is the condition known as hyperinsulinism. In certain individuals the pancreas produces an excessive amount of insulin; sugar is then burned at an abnormally rapid rate. Except when supported by the absorption of sugar from the digestive tract, as during the first two hours after meals, the blood sugar falls to a level lower than normal. The symptoms that develop are typical of mild insulin shock; there is muscular weakness and, in extreme cases, even fainting and convulsions. These symptoms are relieved by eating carbohydrates. Persons suffering from hyperinsulinism find it necessary to eat more than three meals a day. Young people who faint readily when they have missed a meal—faint from hunger—experience in mild degree the symptoms that are more pronounced in those who suffer from severe hyperinsulinism.

Metabolism of Fats.

The supply of sugar in the body normally determines the extent to which fat is used as fuel. If there is a surfeit of sugar beyond the storage capacity, sugar alone is burned until the excess is utilized; as the supply of sugar and glycogen is consumed, a greater proportion of fat is burned. An abundance of fat in the blood, such as occurs after a meal rich in this substance, does not increase the proportion of fat burned, as would be the case with sugar.

Under ordinary conditions there is always sufficient fat to supply the tissues with fuel, for the amount of fat stored in the body is large. But fat is a less efficient fuel for muscular work than is sugar; more heat is produced for the same exertion, and the fatigue is greater. This condition is experienced by those who reduce their weight by dieting and so burn their bodily supply of fat; it is often experienced also during muscular work performed before breakfast when the body's diminished sugar supply is being conserved.

After meals containing fat the substance appears in the blood in the form of globules, an emulsion like milk. If such blood is drawn from the body and allowed to stand, fat separates and floats on top, as does the cream on milk. The excess of fat in the blood is gradually ac-

cumulated in depots about the body, and if the intake of food is habitually greater than the body's needs, this process may continue up to extreme obesity. On the other hand, when the amount of fat absorbed from the digestive system is insufficient to balance the need for fuel, the fat previously deposited reenters the blood. If this deposit and withdrawal of fat is not exactly compensated over any period there is gain or loss of weight. Considerable fluctuations in weight occurring during a single day are due to variations in the water content of the body; they may amount to three or four pounds, even more.

Except in the most extreme emaciation there are deposits of fat about the abdominal organs and beneath the skin. In the latter locality it serves as an insulating layer and conserves the heat of the body. If the subcutaneous layer of fat is consumed, the contour of the body becomes sharp and angular, for it is this layer of fat which imparts graceful curves to the figure. The areas of major deposition differ somewhat in men and women; in men the abdominal wall is the special site, while in women the fat is more evenly distributed, particularly over the legs and arms. The fact that women need less clothing over their arms and shoulders than men has thus a physiological basis.

The combustion of fat takes place in several steps, of which the initial and final stages are given in the following equation:

$$\underset{\text{(fat)}}{C_{51}H_{98}O_6} + 72.5O_2 = 49H_2O + 51CO_2 + 9 \text{ kilocalories}$$

Here the respiratory quotient $\frac{51CO_2}{72.5O_2}$ is 0.71 in contrast to the quotient of 1.0 for carbohydrate.

Metabolism of Proteins.

Proteins are split into their component amino acids during digestion and are absorbed in this form. The amino acids circulate in the blood, from which they are withdrawn as needed by the various tissues. Each tissue selects and stores, to a limited amount, the particular amino acids required for the reconstruction of the proteins peculiar to its cells, the construction of new cells, and the formation of secretions. The liver stores a much greater amount, but without regard to the varieties. In the liver the amino acids are destroyed; some of the liberated carbon and hydrogen is rearranged to form sugar or glycogen to be used as fuel. In the disintegration the nitrogen from the amino acids is split off, carrying with it some of the hydrogen, and is formed into urea which is eliminated through the kidneys. In the tissues the amino

acids in excess of those needed for growth and repair, are likewise broken down and burned, with the formation of urea and ammonia compounds.

During the conversion undergone by the amino acids the sulphur that some contain is mainly separated as sulphuric acid which is combined with sodium or other basic substances and eliminated through the urine.

The Nitrogen Balance.

The nitrogen from the amino acids broken down in the body appears in the urine as urea and ammonia compounds; its amount can be accurately determined by chemical analysis. All proteins contain, within narrow limits, the same amount of nitrogen, about 16 per cent. Therefore the amount of nitrogen eliminated in the urine during a day is an index of the amount of protein broken down in the body during this time. The nitrogen appearing in the urine does not necessarily come from protein which has been recently eaten, for the protoplasm of the body lost in the daily wear and tear is burned in exactly the same manner as any other protein. When the diet is adequate in fats and carbohydrates, but lacking in protein, urea continues to be excreted in the urine, and this nitrogen is derived solely from the disintegrated protein of the body.

The relation between the amount of nitrogen taken in the food and that excreted from the body in the urine[1] is known as the nitrogen balance. When the intake exceeds the output the nitrogen balance is said to be positive—protein is being retained; and when the output exceeds the intake the balance is negative—the body is losing protein.

Determinations of the nitrogen balance under various conditions of diet have given valuable information as to the body's daily requirements of protein.

The Need for Protein.

Protein as a food is far more important for the maintenance of the integrity of the body than for fuel. The breaking down of the protoplasm of the cells of the tissue is continuous; and if the waste is not made good by eating protein, the body ceases to grow and function efficiently. Mild protein starvation may result in lassitude and increased

[1] In precise determinations, account is also taken of the nitrogen in the feces derived from the small amounts of protein that escape digestion, and the even smaller amounts of nitrogenous waste excreted through the walls of the intestine.

susceptibility to fatigue; prolonged starvation, in profound bodily derangement. The effects of an insufficient amount of protein in the diet have been observed on a large scale in children as a result of the low protein ration of war time. The children develop hunger edema, or dropsy, in which the abdomen becomes distended with fluid.

In an adult whose diet contains an amount of protein adequate, or more than adequate, for his needs, the intake and output of nitrogen will be identical in amounts; he will be in nitrogen equilibrium. Individuals convalescing from illness, growing children and pregnant women, if given adequate protein, have a positive nitrogen balance; protein is retained in the body for the formation of new tissue. It is therefore important under these conditions that the diet contain the extra protein needed. The ordinary activities of life have only a slight influence upon the rate at which protoplasm is broken down; not much more meat is needed after a day of violent exertion than after one spent quietly.

The amount of nitrogen excreted daily by an adult of average weight receiving sufficient carbohydrate and fat to satisfy his energy requirements, but no protein, is about 3 grams. Three grams of nitrogen represent the destruction of less than 20 grams of protein. But this simple calculation cannot, for a number of reasons, be applied directly to establish the minimum daily requirement for protein. The actual amount needed to satisfy the body's needs is more than twice as great; 50 grams of protein is a reasonable estimate of the minimum daily requirements.

The amount of protein destroyed daily in the body during protein starvation is the irreducible minimum in tissue existence. The situation is comparable to the income of money by which a man supports himself; below a certain income he can continue to exist but he lives poorly; above a certain income he lives well. The addition of 20 grams of protein daily to the diet of a man on protein starvation will not restore his nitrogen balance to equilibrium; 20 grams in the diet does not correspond to 20 grams destroyed in the tissue. One reason for this fact is that the amino acids from proteins digested in the alimentary tract do not go directly to the tissues where they are needed; instead, a portion is broken down in the liver and so rendered unavailable for tissue needs.

A second reason is that the amino acids present in many foods are in different proportions than those required by the body. The tissues select and use those they need; those unsuited, or in excess, are dis-

carded and burned as fuel. Thus the amino acid content of food protein becomes an important feature in defining dietary requirements. If a single amino acid essential to human flesh is lacking from the proteins eaten, growth and repair cannot take place. The more nearly the protein in the diet resembles human flesh in the number and variety of amino acids, the more economically it can be utilized. Proteins from meat, including eggs and milk, bear the closest resemblance to human protein; the proteins from vegetables, less so. They must be eaten in greater amounts to provide the necessary amino acids in the required proportions. The accompanying table gives the amounts of various common proteins required to supply 50 grams of human protein.

TABLE III.—THE AMOUNT OF VARIOUS PROTEINS REQUIRED TO SUPPLY 50 GRAMS OF HUMAN PROTEIN

Meat protein	50 grams
Milk protein	51 "
Rice protein	57 "
Potato protein	57 "
Bean protein	63 "
Bread protein	127 "
Indian corn protein	170 "

For most individuals on a free choice of diet, meat is the main source of protein. Although 50 grams of meat protein, as from beefsteak, will satisfy the minimum daily requirement of an average adult, this amount is not supplied by 50 grams of meat. Beefsteak—and this is true of all meats—contains water, fat, and other substances in addition to protein. Most lean meats (see Table VI, page 99) contain about 20 per cent of protein; in order to obtain 50 grams of protein from this source it would be necessary to eat some 250 grams of meat, approximately a half pound. Bread contains only about 9.5 per cent of protein, and 127 grams of this variety are required to supply 50 grams of human protein. To obtain this amount of protein it would be necessary to eat three and a half pounds of bread, or more than a loaf, at each meal.

Although bread is not an ideal source of protein, it is a desirable food, for it is an excellent source of fuel. It serves, as do all other foods containing carbohydrates and fat, as a protein sparer. The requirements of the body for energy to be liberated as heat and movement take precedence over those for protein to repair tissues. If the diet does not furnish the needed fuel, the protein of the food, and even of the tissues, will be used as a source of energy. It is a fact of some significance in

regard to reducing diets, to be discussed later, that man cannot, on a diet consisting exclusively of lean meat, satisfy his minimum requirements for protein. In spite of the apparent great abundance of proteins he will have a negative nitrogen balance. The reason is that man cannot eat and digest in a day enough protein to satisfy his requirements for energy. It would be necessary for him to consume daily four to six pounds, or even more, of lean meat, a difficult task. The carnivorous animals, on the contrary, have an enormous capacity for the digestion and utilization of protein.

All physiological evidence points to the fact that man is intended to be neither entirely carnivorous nor entirely herbivorous. It is difficult for him to supply his energy requirements on lean meat alone, and difficult to supply his protein requirements on vegetables alone (unless, as is the case with some dietary extremists, eggs and milk are included as vegetables). Physiologically man is suited to a mixed diet containing, in suitable proportions, both meat and vegetables. Dietary faddism is rarely in the direction of excessive meat-eating; instead it tends toward its exclusion from the diet. On the other hand, the Eskimo, for reasons of necessity, may live and thrive on a diet almost exclusively of animal origin. To most people meat signifies primarily muscle tissue—beefsteak, roast beef, ham, leg of lamb, and so on. The Eskimo does not limit his diet to these cuts from the animals he eats; instead, he consumes much fat, the most concentrated source of energy, and he eats the visceral organs of animals and fish, even bones. In short, he consumes virtually the whole animal and thus derives many substances essential to the body which are not found in muscle tissue. Even the carnivorous animals do not limit their diet to steaks and chops but eat all, or nearly all, of their "kill" as the cat does the mouse.

Since most persons eat much more protein than the body absolutely requires, the kidneys must do more than the minimum of work by reason of the extra urea eliminated through them. A reduction in the intake of protein is often recommended on hygienic grounds and the policy is carried to fanatical extremes by many persons. In such cases it is meat that is limited; but this limitation is not always logical.

Vegetable protein yields exactly as much urea as does meat protein. As pointed out in the previous section, the vegetable proteins do not contain the amino acids in the same proportion as human protein; a greater amount must be eaten to satisfy the requirements of the body. The elimination of urea through the kidneys and the presumed bur-

den on these organs correspond to the amount, and not the source, of the protein; it may therefore be greater on a vegetarian diet than on one in which the minimum protein is supplied from meat.

There is no evidence to show that a diet high in protein harms the kidneys. When the kidneys are diseased and the elimination of waste is impaired, it is desirable to restrict protein. But this restriction is a matter for the physician to decide; not one of general hygiene. The situation in regard to protein and the kidneys is much like that in exercise and the heart. When the heart is damaged the physician restricts exercise; but restricted exercise is not, for this reason, recommended for the normal heart.

Uric Acid and Gout.

In birds and reptiles uric acid, instead of urea, is the main waste product of protein metabolism. In man, only small amounts of this material are formed, and that mainly from certain proteins, especially those contained in sweetbreads, liver and fish roe. Uric acid is also formed from what are known as meat extractions; these are the substances present to some extent in all meats, but particularly in those which form good soups. Beef tea and bouillon are rich in meat extractions; they are appetizing and mildly stimulating, but, contrary to the popular belief which deems them especially nutritious for children and invalids, they are almost totally lacking in food value.

The uric acid formed in the body is eliminated through the kidneys and appears mainly as sodium or potassium urate. In the disease gout the excretion of uric acid is impaired; sodium urate accumulates in the blood and separates as painful deposits about the joints, especially those of the great toes. The fundamental cause of gout is not known; there is an hereditary tendency to the disease; overeating and indulgence in rich wines and also in rich foods are predisposing factors. Chronic poisoning by lead may occasionally result in gout. The lithium salt of uric acid is more soluble than the sodium salt which forms in the body; at one time mineral waters containing lithium were advocated in the treatment of gout and rheumatic conditions then believed to be due to uric acid. No benefit is derived from the lithium, although such mineral waters are still sold.

Gout is an uncommon disease; the many painful joint disturbances, sometimes called gout, rarely have any relation to this disease; they are forms of arthritis (Chapter XVIII). Disturbance of uric acid

elimination, popular beliefs to the contrary, plays no part in "rheumatism."

Rate of Energy Expenditure and Its Measurement.

The rate at which foods are burned is determined by the momentary need of the body for energy. The combustion of fuel and the liberation of energy as both work and heat take place simultaneously, much as in an internal-combustion engine; indeed, some of the combustion follows the work. In this the body differs from a steam engine where the heat is produced first and the work liberated afterward.

There are three main methods of determining the rate at which energy is expended: (1) By direct measurement of the heat eliminated from the body's surface. (2) By calculation from the rate at which oxygen is consumed and carbon dioxide produced by the body. (3) By the calorific value of the diet. Each of these three methods has its own special advantages. The first can be made very exact; it gives an energy value directly, but requires elaborate apparatus. The second requires less apparatus and is more flexible in application; with this method a man's expenditure for as brief a time as one minute can be determined. The third is applicable not only to a single person, but even more easily to a group of people or to a whole nation, but it is accurate only when taken over a long period of time. In the war whole nations were rationed on the basis of just enough food to supply the necessary vital fuel.

Direct Calorimetry.

In the method of direct measurement, the subject is placed in the chamber of a calorimeter and the heat liberated by the body is determined over a period of an hour, a day, or even longer. Provision is made to measure the mechanical energy of any work performed by means of an ergometer. The essential part of the calorimeter is an adiabatic room, a box within a box, from which the heat loss or gain by conduction to the outside is prevented by maintaining the outer walls at exactly the same temperature as the inner by means of delicate electrical controls. A measured stream of water passes through the chamber in a coiled pipe, and the difference in the temperature of the water at entry and exit gives the heat removed from the calorimeter. The results obtained by this elaborate method of direct calorimetry have proved that the principle of the conservation of energy holds true

in living beings, and have demonstrated the theoretical correctness of the simpler method of indirect calorimetry.

Indirect Calorimetry.

In indirect calorimetry the energy developed in the body as both work and heat is estimated from the amount of oxygen consumed and carbon dioxide produced. The subject upon whom the determination is made breathes through a mouthpiece connected to valves which so direct the flow of gases that atmospheric air is inhaled and the exhaled air is passed into a large rubber bag or a gasometer. After a sufficient amount of expired air is collected, its volume is measured and its percentages of oxygen and carbon dioxide are determined by analysis. From the values so obtained the volume of oxygen consumed and carbon dioxide produced in one minute can be readily calculated. These values in turn form the basis for the calculation of the rate of energy expenditure.

It is necessary first to know the nature of the fuel that is being burned in the body. This information is derived from the respiratory quotient, R.Q., which has previously been defined (pages 75 and 78) as the ratio between carbon dioxide produced and oxygen consumed, $\frac{CO_2}{O_2}$. When only carbohydrates are being burned in the body the R.Q. is 1.0; when only fats, 0.71. Any value between these extremes indicates the proportions in which the two fuels enter combustion; thus a value of 0.82 corresponds to one-third carbohydrate and two-thirds fat.

The combustion of these two fuels follows definite chemical reactions (see pages 74 and 78). Thus the combustion of one gram of carbohydrate consumes 0.8 liters of oxygen and is attended with the liberation of 4.1 calories of energy; for the same amount of fat 2 liters of oxygen are used and 9.0 calories of energy liberated. For an R.Q. of 0.82, as given above, each liter of oxygen consumed by the subject of the experiment at this proportion of fuels would correspond to 4.83 calories per minute. If the subject consumed 300 c.c. of oxygen per minute, which is about the average rate for a man at rest, his energy would be 1.45 calories per minute.

For certain types of routine work, as in hospitals, where the rate of energy expenditure is frequently determined for diagnostic purposes, that is, the basal metabolism to be discussed later in this chapter, a simplification is made in the procedure of indirect calorimetry by assuming a normal respiratory quotient of 0.8. Instead of collecting the expired

air the subject is made to breathe back and forth from a small gasometer filled with oxygen or air enriched with oxygen. The carbon dioxide of the expired air is removed by a cartridge of alkali placed in the circuit. The decrease in the volume of oxygen in the gasometer is read directly as the oxygen consumption over the period of rebreathing. This volume, multiplied by the heat equivalent for oxygen at the assumed respiratory quotient (4.8 kilocalories per liter), gives the energy expenditure for the period.

Dietary Calorimetry.

In a state of equilibrium the energy output of the body equals the total calorific value of the diet. The equilibrium of income and outgo ceases if the body gains or loses any considerable weight which would indicate a gain or loss of fat and hence a diet which is not in equilibrium with the energy needs. The dietary method is best suited to approximate the total energy expenditure of a group of people. The heat value of the food purchased by an army cantonment, minus that in the table scrap, is the energy expended by the men fed; the calorific value of the food raised by a nation plus the imports and minus the exports is the energy expended by the people of the nation.

The principle underlying the dietary method of calorimetry has a corollary: in order to maintain the body in a normal state the diet must have a calorific value equal to the energy expended (see Chapter V).

Basal Metabolism.

The rate at which energy is expended by any individual is subject to wide fluctuations according to the muscular activity of the body. The relative expenditure of different individuals under identical conditions of activity depends upon age, size, and muscular efficiency. The amount of energy expended by the body is at a minimum in an individual lying in bed before breakfast (it may be somewhat lower during sleep). This minimum rate of energy expenditure is called the basal metabolism. Determination of an individual's basal metabolism gives nearly the same value day after day. The value found is an essential constant of his body. The energy output is that required to maintain the necessary and never-ceasing operations of the body; to circulate the blood, to keep the body at a normal temperature, and to hold the muscles in that state of slight tension or tonus which dif-

ferentiates the living flesh from the flabby non-resistant state which follows death.

In general, the basal metabolism increases with the body weight, but the increase is not proportionate. The value of the basal metabolism does, however, correspond to the surface area of the body. All normal adults in the basal state have the same heat loss per square meter of the

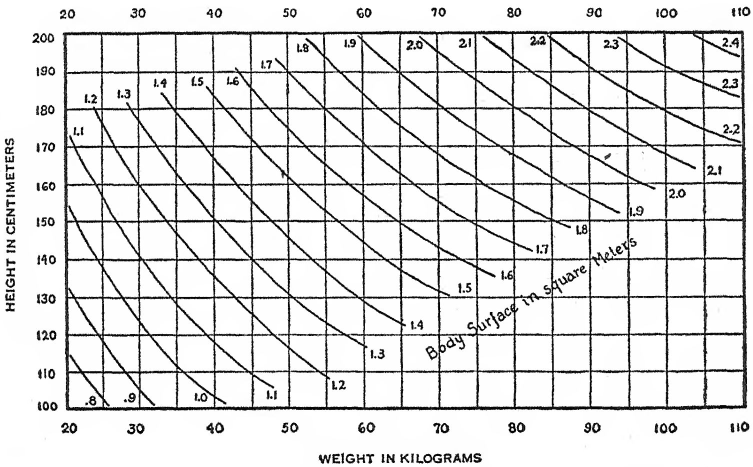


Figure 11. Area of the Body Surface from Weight and Height.

The curve (or interpolated curve) touched by the intersection of a line extending from the subject's weight on the abscissa with a line extending from the subject's height on the ordinate gives the area of the subject's body in square meters.

body surface within ± 10 per cent. The average normal is 39.7 kilocalories per square meter per hour.

It is very difficult to measure directly the area of the surface of the body. This function varies with the relations of weight and height so that a close approximation can be made from these values, which are readily obtained (see Figure 11).

The Thyroid Gland and the Regulation of Basal Metabolism.

Since the basal metabolism is a physiological constant, there must be some mechanism which serves as a governor. The internal secretion of the thyroid gland, thyroxin, furnishes, in part at least, the necessary stabilizing influence. Disturbances in the rate at which this gland discharges its secretion are reflected in abnormally high or low levels of basal metabolism. The determination of the basal metabolism thus

becomes a medical diagnostic measure for certain diseases of the thyroid gland.

The thyroid gland is situated in the neck. It has two lobes, one on each side of the trachea just below the larynx, connected by a narrow strip which crosses the front of the trachea (see Figure 12). The gland

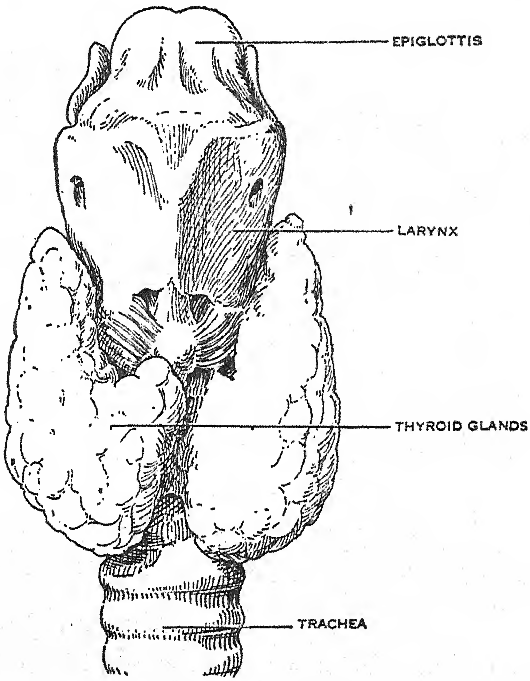


Figure 12. THYROID GLAND.

normally weighs 20 to 30 grams, but in the diseased state of goiter it may enlarge to many times this weight. The most significant fact regarding the secretion of the thyroid gland is that it contains iodine. The body must be supplied with a certain small amount of iodine in order that the internal secretions may be formed. The iodides thus take their place among the necessary foodstuffs.

Simple Goiter.

The term goiter is applied to any chronic enlargement or increased activity of the thyroid gland. In so-called simple goiter the gland gradually, over a period of years, increases in size. In severe cases it may

become enlarged to such an extent that it projects beyond the chin, causing severe disfigurement; it may also interfere with breathing by pressing on the windpipe. In simple goiter the rate at which the gland forms its secretion is not materially altered; consequently there is no marked change in the rate of basal metabolism.

Simple goiter results from a deficiency of iodine in the diet. The condition may be considered as an attempt, on the part of the gland, to compensate for the insufficient supply of iodine by growing larger. This form of goiter is prevalent not only in man, but in domestic animals as well, in regions—goiter districts—where the soil and water have a low iodine content. Such districts occur throughout the world, especially in mountainous regions like the Alps; but in the United States the main goiter district is along the Great Lakes. Goiter is not found near the shores of the sea. Sea water contains an enormous supply of iodine which has been leached from the soil and carried to the ocean by rivers. The dry spray of sea water containing iodine is blown many miles inland so that in these regions iodine is present in food and water in sufficient amounts to supply the dietary requirements.

In inland or mountainous regions where the iodine is deficient, the addition of the necessary small amounts of iodides to the food prevents simple goiter. It is the usual practice to supply the iodine in table salt; in Switzerland all salt sold is iodized. It is much simpler to prevent this type of goiter than to remedy it. In children the development of the goiter is arrested by iodine, and the swelling may disappear. In adults it usually persists.

In disturbances of the thyroid gland other than simple goiter, the secretion of thyroxin is disturbed, with corresponding alterations in the rate of the basal metabolism. The thyroid gland exerts an influence over many bodily functions in addition to the rate of metabolism; the disturbances resulting from abnormal secretion constitute definite diseases. Diminished or hyposecretion gives rise to cretinism and myxedema; excessive or hypersecretion, to exophthalmic goiter.

Cretinism.

Cretinism is a disease which occurs in children as the result of severe deficiency of the thyroid secretion. The disease may occur sporadically, that is, by chance in any locality among children in whom the thyroid gland has failed to develop normally. It also occurs endemically, that is, with high prevalence in some particular locality, among children living in goiter districts and suffering severe iodine deprivation.

A child afflicted with cretinism is stunted in growth and dulled in mentality. The face is large and bloated, the mouth is held partially open and the tongue hangs out. The abdomen is swollen, the legs are thick and short. Growth may stop with a height of three or four feet even though the cretin may advance in age to adult years. The backward mental state frequently lapses into imbecility.

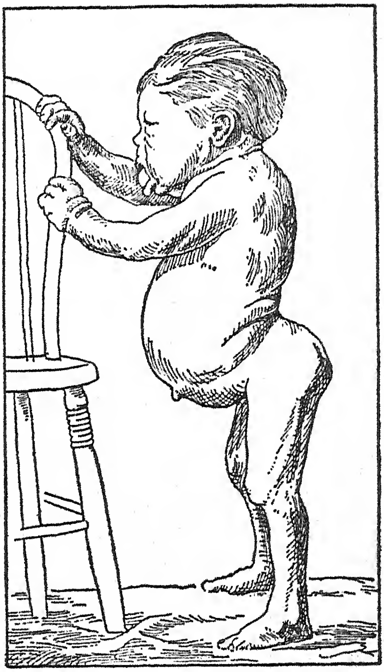


Figure 13. A CRETIN.
About thirty-five years of age.

The deficiency of thyroid secretion, from which a cretin suffers, can be supplied by feeding him the thyroid gland taken from slaughtered animals. The dried extract of this gland is sold as a medicine in the form of tablets. If the administration is started when the child is young, the effects are marked; in the period of a few months, a stupid, malformed creature changes to a normal and rapidly growing child. Except when the disease is due to iodine deficiency, the administration of the thyroid extract must be continued throughout life, or the condition of myxedema develops.

Myxedema.

Myxedema is the disease which a subnormal secretion of the thyroid gland produces in an adult. In most cases the cause for the deficiency is not known. Persons afflicted show an inelastic swelling of the skin which also becomes dry, coarse and roughened; the hair falls out. There is slowness of thought and movement. The face is altered; the features become swollen and coarse; the lines of expression are obliterated, the mouth becomes enlarged, the lips are thickened, and the nostrils broadened. The body increases in weight and is ungainly in appearance. The voice is hoarse. The basal metabolism is below the normal value. As in cretinism, the administration of thyroid extract causes the symptoms to disappear; in a comparatively short time the face loses its brutish appearance, the hair commences to grow, and the mental functions become normal.

Exophthalmic Goiter.

In exophthalmic goiter there is an excessive amount of internal secretion of the thyroid gland. The body loses weight, the skin is flushed and moist with perspiration, the heart beats rapidly, and the hands and tongue tremble. Intense emotional excitement follows slight provocation. The rate of basal metabolism is raised above the normal; in some cases, to more than double. The characteristic protrusion of the eyeballs, from which the disease receives its name, gives the face, in severe cases, an expression of agitation and fear. Mild forms of the disease may also occur, with less severe symptoms.

Exophthalmic goiter may develop in any region, for, unlike simple goiter, it is not caused by a deficiency—or by an overabundance—of iodine in the diet. For reasons unknown, the disease is rare in Switzerland but fairly common in England and the United States, being particularly severe in the latter country. It occurs far more often in women than in men. The cause of the disease is not known; various nervous influences such as worry, excessive social activity, disappointment in love, seem in some cases to be predisposing factors. The rate at which the internal secretion of the thyroid is discharged into the blood is influenced by emotional states; and the increase in turn accounts for some of the bodily phenomena which accompany emotions. The condition of those who suffer from exophthalmic goiter is aggravated by any excitement; recovery sometimes follows prolonged rest in bed. In severe cases, however, it may be necessary to resort to surgical operation in which a portion of the gland is removed.

The administration of thyroid extract to a normal individual is followed by symptoms similar to those of exophthalmic goiter. The heart beats rapidly, excitability is increased and the basal metabolism elevated. The increase in metabolism results in a loss of weight. Consequently thyroid extract has been used for reducing; it is an ingredient —a dangerous one—of some proprietary reducing medicines. Thyroid extract is a potent substance and should be administered only under the supervision of a physician after a determination of the basal metabolism rate has shown the normal secretion to be deficient.

Energy Expenditure and Mental Activity.

The question is frequently raised as to whether mental activity has a measurable influence upon the basal metabolism. Nervous tissue takes oxygen from the blood and returns carbon dioxide, and thereby presumably liberates energy. Nevertheless, all attempts to demonstrate an augmented energy expenditure during mental activity have given indefinite results. The nerves and brain make up only about 4 per cent of the weight of the body, so that even a marked change in the energy liberation of this portion of the body would be unrecognizable in a measurement made upon the body as a whole.

Increase in Metabolism Due to Taking Food.

After protein is eaten the basal metabolism is increased for several hours by as much as 10 to 30 per cent; after carbohydrates and fats, 4 to 6 per cent. This effect is known as the specific dynamic action of food.

Except to keep the body warm, the energy production stimulated by protein is wasted, for it is dissipated wholly as heat. If work is performed after a meal high in protein, the heat is added to that produced by the muscular exertion. A diet rich in protein is therefore unsuited to heavy muscular work during warm weather. Meat is "heating." The much smaller energy production stimulated by carbohydrates and fats is wasted during rest but can, unlike that from protein, be utilized for work.

The increase in metabolism which follows the taking of food is not to be thought of as similar to the increased heat production in a steam boiler on addition of fuel to the fire. The activity is centered particularly in the liver and is probably excited by the changes which take place there in the amino acids and carbohydrates following digestion.

Metabolism and Body Temperature.

A uniform temperature is one of the essential constants of the body. The heat to maintain the temperature comes from the combustion of food; it is dissipated mainly through the skin. The rate of heat production cannot be reduced to accommodate the body to hot surroundings, but the body is equipped with an efficient regulating mechanism by means of which the loss of heat can be controlled but not completely prevented (see Chapter XVIII). In warm climates the heat developed by the metabolism during the quiet state is sufficient, or more than sufficient, to make up the minimum heat loss, and temperature regulation is then entirely a matter of dissipating any excess of heat produced. In cold climates housing, clothing, and artificial heating produce conditions which, so far as the body is concerned, are equivalent to a warm climate. Since these artificial conditions can be varied to suit comfort, heat regulation is carried out for the most part by the same mechanism in both hot and cold climates. When the housing, clothing, and artificial heat are insufficient to duplicate for the body a semi-tropical climate, the heat production during the resting state becomes insufficient to support the normal body temperature. The additional heat needed may then be obtained by exercise. If this is not resorted to, the so-called "chemical regulation of temperature" is called into play to increase the rate of metabolism. This chemical regulation is in reality involuntary exercise. The muscles are first made more tense; they even feel stiff. This static effort involves heat production. If the increased tonus does not furnish sufficient heat the muscles twitch rapidly—the condition called shivering.

Muscular Exertion and Rate of Metabolism.

Muscular work influences the rate of metabolism to a greater extent than does any other condition; the increase of metabolism is proportional to the muscular exertion. In physiology the term work is used in a somewhat broader sense than in engineering, and likewise the word rest. Physiologically, work and rest do not express entirely opposite conditions; they are the same condition varying only in degree. The body, as long as it is alive, is never at rest. In the physiological sense work is always being performed. Even in the most extreme relaxation, the muscles are active and the vital functions of all organs are carried on continuously. In doing work, in the engineering sense of performing a task, the muscles do not spring suddenly from inactivity to activity; they merely increase their activity. The extra energy expended

in performing light manual tasks is often considerably less than that expended by the body in the state of so-called complete rest. Thus a man of average size, lying at rest, expends energy at the rate of approximately 80 calories per hour; on sitting up, but still resting, his energy expenditure, because of the greater tonicity of certain muscles, rises to some 100 calories per hour. The same man, performing an occupation such as typewriting, further increases the expenditure to only about 140 calories per hour.

All muscles function by contracting; their force is expended as a pull upon the structures to which they are attached. If the force of contraction is sufficient to overcome the resistance imposed against the attachments, movement results; work is done in the engineering sense of the word—dynamic effort. If, on the contrary, the force of contraction is not sufficient to overcome the resistance, no movement results and no external work is performed, but nevertheless work is performed in the physiological sense—energy is expended. This static effort, if continued, leads to muscular fatigue as surely as does a similar expenditure of energy upon dynamic effort—a fact familiar to everyone who has held a weight at arm's length.

Within the living body, even during rest, the muscles are liberating energy in static effort. Each of the muscles attached to bones has an antagonist which acts in the opposite direction. Thus the pull of the biceps is opposed by the triceps. All muscles exhibit, even during rest, a state of tonicity or partial contraction; when the tonicity of the biceps equals that of the triceps, the forearm is held stationary. It moves only when the contracting force of one muscle exceeds that of the other. If, however, the contracting force of both is increased, the arm does not move but becomes more rigid. The pull of the muscles may be increased voluntarily; it is also increased involuntarily by mental activity either emotional or intellectual, and by chilling of the skin; a man becomes tense with interest, rigid with fear, or stiff with cold.

In static effort the energy expended by the muscle is dissipated wholly as heat. In dynamic effort the energy expended by the muscle is dissipated in part as heat and in part as the energy of the external work performed. The energy, regardless of the form in which it appears or where it appears, comes from the combustion of fuel food within the tissues. Thus measurement of the rate of metabolism, as by indirect calorimetry, shows the rate of energy expenditure as both heat and work. It also shows the amount of food needed to supply the energy.

When work is performed, the exercising muscles dissipate more energy as heat than they liberate as mechanical energy to perform the work. The proportion of these two is an expression of the efficiency of the muscle. Thus if a muscle expends a total of 100 kilocalories in doing work with an energy equivalent, as heat, of 33.3 kilocalories, the muscle is said to have an efficiency of 33.3 per cent. The efficiency of the muscles ranges from 15 to 35 per cent. The energy as heat and work liberated by the muscle, no matter how great it may be, is not the total energy liberated by the body at the time. To the amount expended in doing the work must be added that expended in maintaining the body at rest. For example: A certain man while sitting still expends energy, as heat, at the rate of 100 kilocalories per hour; he then turns a grindstone by means of a foot treadle, thus doing mechanical work at the rate of 14,167 kilogram meters (101,290 foot pounds) per hour. This amount of work in terms of heat is 33.3 kilocalories. Assuming that the total thermal efficiency of the muscles performing the work is 33.3 per cent, twice as much energy is dissipated from the body in the form of heat as is expended as physical work. The energy cost to the man turning the grindstone for one hour is therefore not 33.3 but 100 kilocalories. This amount added to the expenditure during a similar period of the resting state gives the approximate total energy expended during the hour in which the task was performed. This total is 200 kilocalories.

The amount of food which is required to provide the energy for this expenditure can be calculated readily from the heat value of the foods. The necessary 200 kilocalories would be furnished by approximately 49 grams of sugar (heat value, 4.1 C. per gram), or 22 grams of fat (heat value, 9 C. per gram). As will be seen later, one and one-half glasses of milk or two eggs would also supply this amount of energy. If, instead of turning the grindstone, the man had remained at rest in his chair, his energy expenditure and food requirements, under the circumstances chosen here, would have been one-half as great as they were during the exercise.

The basal metabolism and that during sleep are the lowest rates at which energy can be expended; the highest is that of a man performing the maximum amount of work of which he is capable for even a short time, and may, for a period of a few seconds, run up to forty times the basal; but the maximum for any length of time, as in a boat race or Marathon race, is ten to twelve times the basal.

The accompanying table gives the energy used per hour in various occupations; the values are necessarily merely rough averages.

TABLE IV.—TOTAL ENERGY EXPENDITURE PER HOUR OF A MAN OF AVERAGE SIZE, 70 KILOS (154 LBS.) UNDER DIFFERENT CONDITIONS OF ACTIVITY

	Kilocalories per Hour
Sleeping	60–70
Awake, lying still	70–85
Sitting at rest	100
Standing at rest	115
Typewriting	140
Walking 2½ miles per hour	200
Carpentry	240
Painting	240
Walking 3½ miles per hour	300
Sawing wood	450
Running 5¼ miles per hour	500

The daily energy expenditure and food requirements for a person of average size can be approximated from the values given in Table IV. For example:

8 hours of sleep at	65 kilocalories	=	520 kilocalories
2 hours walking at	200 "	=	400 "
8 hours typewriting at	140 "	=	1120 "
6 hours sitting at rest at	100 "	=	600 "
Energy expenditure and food requirements for the day		=	2640 "

If, for the eight hours of typewriting, there was substituted a similar period of cross-country walking at three and one-half miles per hour, the daily expenditure would amount to 3800 kilocalories.

The daily expenditure in various trades has been estimated at the averages shown in Table V, which are subject to wide individual variations.

TABLE V.—TOTAL ENERGY EXPENDITURE PER DAY OF MEN ENGAGED IN VARIOUS TRADES

	Kilocalories per 24 Hours
Shoemaker	2000–2400
Carpenter or mason	2700–3200
Farm laborer	3200–4100
Excavator (work with pick and shovel)	4100–5000
Lumberman	5000–6000

Six thousand calories is close to the upper limit of the amount of food which can be eaten, digested, and assimilated by even a powerful man in one day.

Running at the rate of five and one-fourth miles per hour, a man will go approximately fifty miles on an energy expenditure of 4,000 kilocalories, the heat equivalent oı ne pound of fat and approximately that of one *pint* of gasoline.

CHAPTER V

THE COMPLETE NORMAL DIET

THE PRINCIPLES OF HUMAN DIETETICS ARE SIMPLE AND EXPLICIT, BUT THERE are few subjects about which there is more misunderstanding, faddism and superstition than that of diet. The superstitions range from the absurd belief that eating fish develops brains, to the conviction that since a man is a product of his food the diet of Napoleon and Newton supplied the material of their genius—it did, but only in calories, proteins, vitamins and minerals, the same calories, proteins, vitamins and minerals that provide flesh and fuel for an imbecile. Dietary fads, particularly those for reducing body weight, have been responsible for much ill health from dietary deficiency. There is no reason for the misunderstanding of dietary requirements except ignorance: they are simple and definite. A complete normal diet is one which provides all essential foods in the amounts needed for the body's maintenance and its energy expenditures. Specifically these requirements are: (1) fuel foods, (2) protein, (3) minerals, (4) vitamins and (5) roughage.

The Supply of Fuel Foods.

The expression "food requirements" has been used in previous sections to signify the calorific or fuel value of the food that must be eaten in order to balance the body's energy expenditures. Thus, if a man during twenty-four hours expends 2250 kilocalories, this energy can be supplied by a food intake having this heat content. This amount of energy could be derived from 549 grams of carbohydrate or 250 grams of fat (see Chapter I). We do not, however, live on chemically pure and dried foodstuffs. With the exception of some of the fats and such purified materials as sugar or cornstarch, the common foods contain not only various proportions of carbohydrates, fats, and proteins, but also other substances such as water and inorganic salts from which no energy can be derived. In order to convert food requirements expressed in terms of heat into amounts for the various foods eaten in a mixed diet in their normal moist form, it is necessary to know the calorific value of the common foods. This information is set forth in

TABLE VI.—APPROXIMATE NUTRITIVE CONTENT AND CALORIFIC VALUE OF SOME COMMON FOODS

Food	Available Nutrition of Edible Portions				
	Composition			Heat Value	
	Protein, Per cent	Fat, Per cent	Carbo-hydrate, Per cent	Kilocalories per pound (or pint of fluid)	Approximate amount, as served, yielding 100 kilocalories
FRUIT					
Watermelon	0.3	0.2	6.0	125	Medium serving
Cantaloupe	0.5	0.0	8.4	160	1 small
Grapefruit	0.5	0.4	8.6	170	½
Orange	0.6	0.2	10.5	210	1 large
Apple	0.3	0.5	12.8	260	1 large
Banana	1.0	0.5	20.0	400	1 large
VEGETABLES					
Cucumbers	0.6	0.2	3.0	75	2 medium-sized[a]
Celery	0.8	0.1	3.2	80	25 pieces
Lettuce	0.9	0.3	2.9	85	2 to 3 heads[a]
Asparagus	1.3	0.2	3.3	95	15 to 25 stalks
Spinach	1.6	0.3	3.2	100	2 cups
Tomatoes (raw or canned)	0.7	0.4	3.8	100	3 medium-sized
Radishes	1.0	0.1	5.6	130	25 to 30
Cabbage	1.2	0.3	5.5	140	1½ to 2 cups
Beans, string	1.7	0.3	7.2	180	1½ to 2 cups
Carrots	0.7	0.4	8.9	200	4 medium-sized
Squash	1.1	0.5	8.6	205	1 cup
Beets	1.2	0.1	9.4	205	2 cups
Onions, raw	1.2	0.3	9.6	215	3 to 4 medium
Potatoes, baked or boiled	1.9	0.1	20.0	415	1 medium[b]
mashed	2.0	2.7	17.1	475	½ cup
Peas	5.2	0.5	16.7	430	¾ cup
Beans, lima	5.3	0.6	21.6	525	½ cup
baked	4.8	2.3	19.6	565	⅓ cup
CEREAL PRODUCTS					
Oatmeal, cooked	2.3	0.5	11.3	285	⅓ cup with milk and sugar
Macaroni, cooked	2.3	1.4	15.6	405	1 cup (if with cheese, ½ cup)
Rice, boiled	2.3	0.1	23.8	505	½ cup
Rice pudding or tapioca	2.5 / 3.5	3.54	28 to 30	715 / 825	⅓ cup

TABLE VI (*Continued*)

Food	Available Nutrition of Edible Portions				
	Composition			Heat Value	
	Protein, Per cent	Fat, Per cent	Carbo-hydrate, Per cent	Kilocalories per pound (or pint of fluid)	Approximate amount, as served, yielding 100 kilocalories
Pie	2.5 3.5	5.55 8.5	21 to 42	800 1200	piece 1 to 2 in. at edge
Bread, brown	4.2	1.6	46.2	1035	2 medium slices
corn	6.5	4.2	45.2	1170	3 to 4 cu. in.
rye	7.3	0.5	52.0	1160	1 average slice
whole wheat	7.5	0.8	49.1	1125	1 average slice
white	9.6	2.0	57.3	1284	1 average slice
rolls	6.9	3.7	52.8	1360	1 roll
toast	9.9	1.4	66.3	1390	1 slice[c]
Cake, cookies, doughnuts	4.5 6.5	7.5 1.9	52.0 74.0	1580 1895	2–3 cu. in. ½ doughnut
Wheat breakfast foods	9.3	1.6	74.0	1670	⅓ cup with milk and sugar
Crackers	7.5 8.5	7.5 10.5	68.0 72.0	1830 1920	2 graham 6 saltines or 4 soda
MEAT PRODUCTS					
Clams, oysters and lobsters	6.0 16.0	1.2	0.5 4.0	215 425	6 to 10 oysters ¾ cup lobster
Fish, fresh	11.0 22.0	0.5 10.0		300 cod 750 lake trout	
Salmon, canned	21.1	11.5		915	
Sardines, canned	22.3	18.7		1250	4 to 6
Chickens, young	20.9	2.4		502	
fowl	18.7	15.5		1040	
Veal	19.7	7.3		710	
Beefsteak, lean	19.1	12.1		900	
medium fat	17.9	19.2		1185	
fat	17.0	26.2		1470	
Beef, roast	21.6	27.2		1410	
Lamb, chops	21.0	28.4		1640	
leg	19.1	12.1		905	
Frankfurters	19.0	17.7	1.1	1160	1 small
Pork, ham	15.8	36.9		1905	
chops	24.1	35.7		2020	
bacon	9.6	64.0		2950	
MISCELLANEOUS					
Pea soup	3.6	0.7	7.6	232	¾ cup[d]

TABLE VI (*Concluded*)

Food	Available Nutrition of Edible Portions				
	Composition			Heat Value	
	Protein, Per cent	Fat, Per cent	Carbohydrate, Per cent	Kilocalories per pound (or pint of fluid)	Approximate amount, as served, yielding 100 kilocalories
Milk, whole	3.3	4.0	5.0	314	5/8 glass
Gelatin (jelly)	4.2		17.4	410	1 cup
Eggs	11.9	9.3		594	1 1/3 eggs
Cream, medium	2.4	17.6	4.5	860	1/4 cup
Molasses			70.0	1255	1 tablespoon
Maple syrup			71.0	1270	1 tablespoon
Honey	0.4		81.2	1481	1 tablespoon
Sugar, white			100.0	1790	3 teaspoons
Cheese (average)	25.1	32.0	2.0	1885	3/4 cu. in.
Nuts	13.0 23.0	35.0 60.0	22.0 10.0	2255 2980	20 peanuts 15 almonds 12 walnuts 2 Brazil nuts
Butter	1.0	85.0		3491	1 tablespoon

[a] Without dressing; 1½ tablespoonful of French dressing, or 1 tablespoonful of mayonnaise, yields 100 kilocalories.

[b] The addition of butter may more than double the heat value.

[c] The greater heat value of toast as compared to bread is due to decrease in weight from the removal of water during toasting.

[d] Soups vary greatly in heat value. One hundred kilocalories are supplied by ½ cupful of creamed soup, 1 cupful of thin soup, such as vegetable or chicken, and 3 to 5 cupfuls of consommé and bouillon.

extensive tables issued by the United States Department of Agriculture and furnished on request. The accompanying table presents the average nutrient composition and fuel value for some of the more common foods.

From this table it is seen that butter has the highest fuel value of any of the foods given; bacon ranks second. The salad vegetables, such as lettuce and cucumbers, have the lowest fuel value, but the oil dressing with which they are customarily served may make a considerable calorific contribution. The vegetables as a whole have a low heat value, with baked beans highest at 565 kilocalories per pound, and peas and

potatoes next at about one-half this value. The cereal products, such as bread, rice, and macaroni, range between 400 and 1900 kilocalories per pound. The fuel values of the various meats are determined largely by the amount of fat which they include; they contain only small amounts of carbohydrate and the percentage of protein does not vary greatly. The heat value of a pound of moderately fat beef is nearly three times as great as that of a similar quantity of lean beef. A half-pint glass of milk furnishes 150 kilocalories, and two eggs give the same amount of heat. A one-ounce slice of bread yields 80 kilocalories, but when spread with half an ounce of butter the heat value is doubled, and the addition of a moderate layer of honey, half an ounce, brings the total to some 250 kilocalories. Eight or nine slices of the buttered and honey-coated bread are sufficient to satisfy the daily fuel needs of an office worker, but they do not supply all of the other requirements of a complete normal diet.

The calorific value of the common beverages depends mainly upon the carbohydrate content; thus tea and coffee, without cream or sugar, have virtually no food value; the addition of 1 teaspoonful of cream and 2 of sugar to a cupful gives a calorific value of 100 calories. This same amount of energy is given by ½ cup of cocoa or 1/3 glass of ice cream soda. The heat value of alcoholic beverages depends upon the content of alcohol; except for the most dilute, like beer, it is high, about 200 calories for the average drink (see section on alcohol, this chapter).

Supply of Protein.

The minimum supply of protein necessary for the maintenance of the human body has been discussed in detail under the section devoted to the metabolism of protein (see Chapter IV). The percentage of protein in some of the more common foods is given in Table VI. Meat contains the highest percentage of protein; with the exception of bacon, the value averages approximately 20 per cent. This protein, moreover, can be reconstructed without loss into that of human flesh, as is also the case with the proteins from eggs and milk. The cereal products and also beans contain approximately one-half as much protein as meat. In these vegetables, however, the amino acids are not in the same proportion as in human protein, and they must therefore be taken in greater quantities than the protein of meat in order to supply the necessary minimum of 50 grams of human protein.

Supply of Mineral Foodstuffs.

The body requires for its growth, repair and proper function, a number of elements classed as minerals. Under ordinary conditions the average adult excretes daily in the urine, feces and sweat, about 30 grams of minerals. They are lost from the body and must be replaced by the diet. With the exception of calcium, iron and iodine, the needed minerals are usually supplied in adequate amounts by any reasonable mixed diet.

Sodium.

Sodium and chlorine are supplied by table salt and by meat. A man needs more sodium chloride in his diet than perhaps any other animal, for he is one of the few that sweats. Sweat contains sodium chloride. In hot surroundings and in violent exertion the loss of salt from the body may exceed the ordinary intake. Sodium chloride starvation that then results may give rise to heat cramps. There is severe pain in the muscles and tingling sensations in the fingers and toes. The condition is relieved by taking sodium chloride, and is prevented by increasing the amount of this substance in the diet in cases where excessive sweating occurs. Many people acquire a taste for salt and use it as a condiment in amounts far in excess of their dietary needs. Contrary to the popular belief that eating salt makes the bones brittle and the arteries hard, there is in reality little harm in this practice except for those whose kidneys are diseased. For infants, and also for invalids with damaged kidneys, the intake of a large amount of salt may lead to a considerable retention of water in the body. It increases the weight of anyone temporarily because of the weight of the water taken to assuage the thirst caused by the salt. Taken with or after much salt, water is eliminated through the kidneys more slowly than if taken without the salt; in fact, it passes out only at the rate that the salt is eliminated. A diet low in salt, such as a milk diet, may contrariwise be followed by temporary loss of weight from water elimination.

Calcium.

It is lime salts, the carbonate and tribasic phosphate, which give stiffness to the bones and teeth. Calcium is also an essential constituent of the blood, necessary to clotting. There is a greater weight of calcium in the body than of any other mineral element—about 1.5 per cent of the body weight. Calcium is constantly excreted from the body, mainly through the walls of the intestines. It has been estimated for

an adult that about 0.6 gram a day is needed to replace the loss; an even greater amount, one gram or more, is required by growing children and women who are pregnant, because bones are being formed; nursing mothers require more because of the calcium lost in the milk.

The metabolism of calcium is intimately tied up with that of phosphorus, for the two go together in the formation of bone. Phosphorus is present in adequate amounts in any reasonable diet and is derived from proteins, especially those of meat, milk and eggs. The utilization of calcium and phosphorus in the body is influenced by the internal secretion of the parathyroid gland (see page 412); abnormalities in the functioning of this gland lead to certain disturbances, fortunately rare, in the metabolism of calcium. The absorption and elimination of calcium and the deposition of this mineral in the bones and teeth are greatly influenced by vitamin D; when the vitamin is deficient in the diet, calcium cannot be properly absorbed or utilized, and diseases of the bones such as rickets and osteomalacia may result. What is important here is the fact that these same diseases may result even when the supply of vitamin D is adequate, if insufficient calcium is supplied in the diet. No amount of vitamin D will compensate for a shortage of calcium. It is probable that the American diet is more often deficient in calcium than in any other mineral. The diseases resulting from abnormalities of calcium metabolism caused by disturbances in the three controlling factors, parathyroid secretion, vitamin D, and calcium food supply, will be discussed under diseases of the bones in Chapter XVIII.

There is a wide difference in the calcium content of various foods; meat is exceedingly poor in it, and milk is so rich in it that less than one quart supplies the daily need. Egg yolk, and to a less extent dried beans, contain more calcium than do most foods; but milk, cheese and other dairy products excepting butter, are the main sources. To obtain the essential amount of calcium deos not mean that milk must be taken as a fluid; milk enters into the culinary preparation of pastry, soups, creamed vegetables, custards, ice cream, and many other dishes. The milk supply for a family or any group served from a common kitchen should average a quart a day per person.

Iron.

Next to calcium, the mineral most commonly deficient in the diet is iron. Iron is a constituent of the red coloring matter of the blood, hemoglobin, which is continually formed in the body. A small amount of iron is lost each day, mainly from excretion through the alimentary

tract; unless over a period of time the loss is made good by iron from the diet, hemoglobin cannot be formed, and its amount then diminishes, giving rise to a condition called anemia. It is estimated that 15 milligrams of iron in the daily diet are sufficient for the average need. After loss of blood from any cause the body for a time needs more than the ordinary supply of iron. The requirement for women, by reason of the menstrual flow, is somewhat higher than for men.

A very small amount of copper in the diet appears to be essential to the proper utilization of iron. There is rarely a deficiency of this mineral.

Egg yolk, molasses, whole wheat, dried beans, peas, spinach and prunes are foods particularly rich in iron; the relative content in equal weights of the foods is in the order named. Meat is not included here for the reason that its iron content varies nearly in proportion to the amount of blood which it contains. Lean meat from which the blood has not been washed, as it is from *kosher* meat, is an excellent source of iron—in fact, one of the main sources for most individuals. Milk is low in iron; it does not contain an amount sufficient to supply the needs of a nursing infant. The deficit in this case is compensated by a supply of iron which is stored in the body of the infant prior to its birth; the necessity of furnishing this supply during pregnancy devolves upon the mother. The once widely advertised virtue of raisins

TABLE VII.—SHOWING THE WEIGHT OF SOME COMMON FOODS WHICH WILL SUPPLY 15 MILLIGRAMS (¼ GRAIN) OF FOOD IRON

Food	Weight of Food Required to Supply 15 mg. of Iron, Ounces
Molasses	6
Dried beans	7
Dried peas	8
Shredded wheat	9
Spinach	11
Oatmeal	11
Prunes	11
Olives	11
Lean beef	11
Eggs	16
Boston brown bread	16
Graham bread	16
Raisins	24
White bread	48
Milk	200

as a source of iron is not substantiated by fact; neither is the popular belief that grape juice and port wine are rich in iron. Table VII gives the comparative weights of some common foods which will supply 15 milligrams of food iron.

Supply of Vitamins.

Physiological experimentation has shown that animals fed upon chemically pure foodstuffs soon cease to grow and become ill, although the diet satisfies the needs for energy, protein, minerals and roughage. The addition of such natural foods as milk, fruit, vegetables, and cereals to their diet restores health and growth. There are present in certain foods minute amounts of substances essential to the well-being of the body; these substances are called vitamins. The word "vitamine" was coined in 1911 in the belief that chemically these food ingredients were "amines"; as the prefix "vita" signifies life, "vitamine" thus meant an amine essential to life. This idea of the chemical structure is no longer held, and many people now use the abbreviated term "vitamin." Although not named until recent years, some conception of these beneficial substances existed nearly two centuries ago, for even then fruit juices, fresh vegetables, and herbs were used to treat scurvy, a disease now known to be due to a deficiency of one of the vitamins.

The discovery that a number of different vitamins existed and the uncertainty of their chemical composition led to their designation by letters of the alphabet. The vitamins first recognized as necessary for human beings were the four, A, B, C, and D, with the yet unsettled possibilities of a fifth, E. It is certain that this list does not exhaust the requirements and that others as yet undiscovered will be added, for investigation in this field of dietetics is being carried forward rapidly. It has already been shown that in some instances the primary letter designations cover not single vitamins but, instead, groups of closely associated vitamins. Thus the original vitamin B group is now known to consist certainly of two, and probably of several more; the two definitely isolated are usually designated as B_1 and B_2, occasionally as B and G or F and G. Similarly it is possible that so-called vitamin D consists of more than one vitamin.

The solubility of vitamins in fat or water is a distinguishing feature that to some extent indicates their sources. Thus vitamins A, D and E are fat soluble; B and C, water soluble. The vitamins derived from the diet act upon the body much as do the hormones produced by the

body in the glands of internal secretion. They are not ferments or enzymes; they influence nutrition and control the functions of tissue by virtue of their specific chemical structure.

Present knowledge of vitamins has revolutionized modern dietetics especially for infants and children. Growing children need a greater amount of the vitamins than do adults. They also appear to absorb them better from the digestive tract. With age the vitamins in the diet may not be well utilized; for this reason it is sometimes essential to have a high vitamin content in the diet of the aged.

Vitamin A.

Vitamin A is primarily of vegetable origin, but the vitamin itself may not be in the plant from which it is derived, for the body is capable of converting a yellow vegetable pigment, carotene, into vitamin A. This substance is found only in yellow and green vegetables; in the latter its yellow color is obscured by green pigments. Thus the outer green leaves of lettuce are a good dietary source of vitamin A, while the inner white leaves contain little. The yellow sweet potato provides vitamin A; the common white potato little, as likewise is the case with white sweet corn, cabbage, and radishes. Raw carrots, yellow corn, spinach, cress, bananas and cantaloupes are good sources of vitamin A. Vitamin A occurs in certain fatty animal foods such as cream, butter, egg yolk and the oil from fish livers; it is derived from vegetable substances eaten by the animals and stored in the fat.

The disturbances of nutrition and health that follow deprivation of a particular vitamin, when all others are present in the diet, indicate the special functions subserved by this vitamin. It was first observed that young animals—and young human beings—cannot grow when deprived of vitamin A. It was therefore called the growth-promoting vitamin, but the fact remains that growth is likewise interfered with when any one of the other important vitamins is absent from the diet. Deficiency of vitamin A leads specifically to disturbance in the secretion of glands and the growth and repair of mucous membranes. One of the most striking effects is seen in the eye; the secretion of tears is diminished and in consequence the front of the eye becomes roughened and easily infected. In the mucous membrane of the respiratory and urinary tracts the deficiency leads to an abnormal growth with loss of resistance to infection. These facts have led to the belief that vitamin A builds up the body's resistance to infections. Such is probably true only when this vitamin is added to a diet in which it was

TABLE VIII.—VITAMINS PRESENT IN SOME COMMON FOODS

– indicates that the food is not a good source of the vitamin.
x indicates that the food contains the vitamin.
xx that it is a good source.
xxx that it is an exceptionally good source.

Food	Vitamins A	B_1	B_2	C	D	E
VEGETABLES						
Beets	x	x	–	x	–	x
Cabbage, raw	–	xx	xx	xxx	–	–
cooked	–	–	–	x	–	–
Carrots, raw	xx	xx	x	xx	–	–
cooked	–	–	–	x	–	–
Celery	xx	–	–	xx	–	–
Cucumbers	x	–	–	xx	–	–
Lettuce	xx	xx	x	xxx	–	xxx
Peas	x	x	–	xx	–	–
Potatoes, raw	x	xx	x	xxx	–	–
cooked	x	–	–	xx	–	–
Beans, string	x	x	–	xx	–	–
Tomatoes	xx	xx	x	xxx	–	xx
FRUITS						
Apples	x	x	x	xx	–	–
Cantaloupe	xx	–	–	xx	–	–
Grapes	x	–	–	–	–	–
Grapefruit	x	–	–	xxx	–	–
Lemons	x	–	–	xxx	–	–
Oranges	x	–	–	xxx	–	x
Peaches	x	–	–	xx	–	–
Pineapples	xx	–	–	xx	–	–
Raspberries	–	–	–	xx	–	–
Strawberries	x	–	–	xx	–	–
CEREAL PRODUCTS						
Wheat, whole grain	x	xx	x	–	–	x
White flour	–	–	–	–	–	–
Rice, unpolished	x	xx	x	–	–	–
polished	–	–	–	–	–	–
Cornmeal	x	xx	x	x	–	x
MEAT PRODUCTS						
Bacon	–	–	–	–	–	–
Beef	–	xx	xx	–	–	xx
Fish muscle	–	x	–	–	–	–
Ham	–	x	x	–	–	–
Mutton	–	xx	xx	–	–	–
Oysters	xx	–	–	x	xx	–
Egg, yolk	xx	xx	x	–	xxx	xx
white	–	–	xx	–	–	–

TABLE VIII (*Concluded*)

Food	Vitamins A	B_1	B_2	C	D	E
Milk, whole	x	x	xx	x	—	—
Butter	xx	—	—	—	xx	xx
Lard	—	—	—	—	—	x
Cod liver oil	xxx	—	—	—	xxx	—
Halibut liver oil	xxx	—	—	—	xxx	—

previously deficient. There is as yet no adequate evidence to support the belief that taking an extra large supply of vitamin A in any way lessens the occurrence of respiratory infections such as head colds.

One of the first and most delicate signs of deficiency in vitamin A is night blindness. Vision fails during dim illumination; the individual thus affected can see clearly in the daytime but is unable to see in twilight.

Vitamin B Group.

Vitamins B_1 and B_2 usually occur together but often in different proportions; a few foods, such as egg white, beans and peas, contain one but not the other. The cereals, wheat and rice, with limitations discussed below, are good sources of B vitamins; so also is yeast. This group is present in many vegetables, particularly raw cabbage, tomatoes, raw carrots, lettuce and spinach; others such as celery, cucumbers and cooked potatoes, cabbage and carrots contain little. The B vitamins occur in eggs, milk, beef and mutton, but most fruits contain little, and oily foods, such as butter and olive oil, none. The distribution of vitamin B in the various parts of cereal grains is of great importance in relation to the preparation of these foods for consumption. In wheat it occurs mainly in the germ, and in rice only in the skin. In making white flour the germ is removed as is the skin of rice during polishing. The B vitamins, particularly B_1, are destroyed by prolonged heating—more quickly in the presence of alkalies.

Deficiency of vitamins of the B group in the diet leads to fundamental disturbances in the nutrition of the tissues of the body. The effects of lack of B_1 are most marked upon the intestines and nerves; of B_2, upon the skin and mucous membranes. Mild deficiency of B_1 is followed by loss of vigor and decrease in the tone of the intestinal muscles; loss of weight and constipation result. Prolonged severe de-

ficiency may lead to the disease beriberi. Deficiency of B_2 may be followed by pellagra.

Beriberi is primarily a neuritis, an inflammation of nerves; paralysis, pain and wasting of the muscles follow; the heart may be affected and death result unless the diet is altered. Many thousands of cases of this disease developed among the Japanese soldiers and sailors during the war between Japan and Russia. The diet of the soldiers consisted largely of polished rice. Beriberi has occurred extensively among the Malays, Chinese and Filipinos, and there have been occasional outbreaks among inmates of asylums in the United States.

In its widest occurrence beriberi is a disease of rice eaters; similarly pellagra is a disease of corn eaters and as such has occurred particularly in the southern portion of the United States. The corn itself does not contribute directly to the disease except in so far as its protein is not well suited for human needs; the association of corn and pellagra results from the fact that in certain regions many individuals make the inexpensive cornmeal the main item of diet. In pellagra, rough and inflamed areas appear on the skin; the tongue is sore and red; digestion is disturbed; eventually muscular weakness and severe mental disturbances may develop. The skin changes characteristic of this disease appear wherever the sun strikes the skin, the back of the hands, the neck, nose and cheeks. There is still some question as to whether pellagra is due solely to deficiency of vitamin B_2 or depends upon the association of other factors. The fact remains that the disease can be prevented by the addition of vitamin B_2 to the diet.

Vitamin C.

Vitamin C is found in nearly all fruits and vegetables and in particularly large amounts during the actively growing phase. The citrus fruits, tomatoes (canned as well as fresh), raw cabbage and lettuce, are particularly rich in vitamin C; the cereals and meats contain virtually none. This vitamin has been isolated chemically and named ascorbic acid; it has the formula $C_6H_8O_6$. Vitamin C is broken down by oxidation when exposed to the air as in the drying, aging and storage of food; it is destroyed by heat and by contact with alkalies.

Vitamin C is apparently unnecessary for chickens, rats and dogs, but is essential to man. Deficiency leads to the disease scurvy in which the main damage is to the blood capillaries. The injury to these vessels, if extreme, may result in hemorrhage within the tissues.

Scurvy was formerly common among sailors who lived for long

periods on a diet of dried and salted food. Nearly two centuries ago it was found that the addition of fruit juice to the diet prevented and cured the disease. The men in the British navy are to this day designated as "lime-juicers" from the fact that sailing regulations dating from 1795 required that this source of vitamin C be carried on all vessels and administered to the crews. Scurvy has occurred occasionally in charitable institutions; it has been found in settlements of foreign populations, such as the Hungarians, Bohemians, and Italians in the mining district of Pennsylvania. Scurvy occurs in infants if fruit or vegetable juice is not included in their diet.

The disease is insidious in its onset, and probably many people suffer from the milder symptoms without the disease being recognized, for deficiency of vitamin C is common. In the severe and definitely recognized form of scurvy, there is loss of weight, progressive weakness and pallor. The gums become swollen and spongy and bleed easily. The teeth may become loose and even fall out; the breath is foul. Open sores may develop on the skin and the joints become painful from the hemorrhages that occur in them. The mind is depressed and indifferent.

Vitamin D.

Vitamin D is not as widely distributed in nature as are the vitamins A, B and C; egg yolk and fish liver oil are the main sources. The vitamin D content of butter is variable; vegetables, fruits and cereals contain virtually none. In sharp contrast to this limited distribution is the fact that vitamin D can be manufactured in the human body; it can also be made synthetically as a chemical preparation.

In the skin of man there are present substances chemically related to the fats which, when acted upon by ultra-violet light from the sun rays, are converted into vitamin D. The vitamin is carried away in the blood and used at once or stored for future use. Some hairy animals whose skin is not reached by the sun apparently secrete the oily precursor of vitamin D from the skin; carried on the hairs it is exposed to the sunlight and converted into vitamin D which is swallowed when the animal licks its coat.

Only a portion of the wave lengths included under the designation of ultra-violet light can activate the synthesis of vitamin D in human skin. The effective range lies between wave lengths of 313 to 250 mμ; the sun rays contain no light with a wave length shorter than 290. It is a highly important fact that dust, smoke and clouds greatly reduce the passage of ultra-violet light from the sun, and that ordinary win-

dow glass shuts out all waves shorter than 320 $m\mu$. Ultra-violet light cannot pass through thick clothing; its penetration of the skin is impeded by tan which is a protection formed by the body against excessive exposure to ultra-violet light, the cause of sunburn. Many conditions of life under civilization in temperate regions conspire to reduce the formation of vitamin D in the body; these are exaggerated in the case of dark-skinned people physiologically suited to strong sunlight who make their homes in northern cities.

Vitamin D, perhaps more than any other, is deficient in the ordinary mixed diet. Fortunately most adults need very little to maintain a normal calcium metabolism; they rarely suffer from any deficiency. On the contrary, much of this vitamin is needed for growing children and women who are pregnant or lactating. Deficiency of vitamin D results in malformation of the teeth (see page 23) and bones; it is the cause of rickets, to be discussed later. The bone changes may lead to bowlegs, knock-knees, deformed chest and skull, and abnormalities in the shape of the pelvis which are of great importance in regard to childbearing. The inadequacy of vitamin D in the diet can be remedied by the daily administration of oil from cod or halibut liver. Under the direction of the physician a synthetic preparation of vitamin D may also be administered; it is prepared by irradiating a substance known as ergosterol with ultra-violet light.

Vitamin E.

Vitamin E is found in green vegetables and the germs of various seeds, especially wheat, which is removed during the milling process necessary for white flour. Male rats fed on a diet deficient in vitamin E lose the power to form spermatozoa, and female rats are unable to bear young. It is not probable that human beings subsisting on any ordinary mixed diet suffer from severe deficiency of this vitamin.

In recent years much publicity has been given to information about vitamins; the impressions left are sometimes misleading. In order to insure growth and vigor and to prevent disease, the diet must contain vitamins A, B_1, B_2, C, D and possibly E. These vitamins can be obtained in adequate amounts from ordinary articles of diet except during periods of rapid growth when especially large amounts are needed. Only under exceptional conditions, and then best at the advice of a physician, is it necessary to enrich the diet with commercial preparations of vitamins. Instead, it is desirable to plan meals so that the

vitamins are abundantly supplied by natural food which yields not only vitamins but minerals and roughage as well.

Supply of Roughage.

By "roughage" is meant food material having a large undigestible residue which will give bulk to the material in the intestines and thus promote their movements. The term is derived from the feeding of farm animals, where it applies to fodder in distinction to rich grain feeds. Roughage is supplied best in the human diet by green vegetables, particularly the salad vegetables and the pulp of fruits. The use of fruit juice rather than the whole fruit is at the expense of roughage. The amount of roughage needed in the diet cannot be accurately predicted; it should be included daily in amounts which the individual has found sufficient to cause easy movement of the bowels. There is no advantage in an overabundance of roughage and there may be actual harm, especially if the material chosen is rough and irritating. Man is not an herbivorous animal; his intestine when normal will handle reasonable amounts of roughage but it is not intended to cope with great masses of coarse, undigestible material. Irritation and even serious injury may follow from the indiscreet use, often dictated by dietary faddism, of large quantities of raw fibrous vegetables or bran. In diseases of the stomach, such as ulcers, or of the intestine, such as colitis, great caution must be exercised in the use of roughage.

Calculation of the Adequacy of a Diet.

The needs of the body for protein, minerals and vitamins are independent of the energy expenditures. A girl working at a sedentary occupation, as in an office, needs as much of these substances as does a lumberman engaged in his heavy labor; a woman during pregnancy and during the time she nurses her child needs even more. The following calculations are not intended as a guide to diet, but merely to show a method of estimating the adequacy of a diet.

In the section on the fuel value of food it was stated that 8 slices of bread spread with butter and honey would supply 2000 kilocalories and would therefore satisfy the entire daily needs of fuel for the average office worker. Let us consider now the inadequacies of this diet.

From the percentage of nutrients given in Table VI, and from the weight of 8 slices of bread, butter and honey, the amount of protein is calculated as follows:

250 grams (8 oz.) of bread containing 9.6 per cent protein	= 24 grams
125 grams (4 oz.) of butter containing 1.0 per cent protein	= 1.25 grams
125 grams (4 oz.) of honey containing 0.4 per cent protein	= 0.5 grams
Total protein = 25.75 grams	

It was stated in the section dealing with protein requirements that 50 grams of meat protein are the daily minimum; the diet under question furnishes only about half this amount of protein and none is from meat, milk, or eggs. Most of the protein here is derived from bread. Because of its deficiency in certain amino acids, 127 grams of bread protein are required instead of the basic 50 grams which refers to a protein complete in all the amino acids necessary for human protoplasm. The protein of one quart of whole milk would add 33 grams, but the total would still be slightly below the desirable amount. The addition of two eggs, which contain 15 grams of protein, would more than complete the requirement. The milk and eggs would add 750 kilocalories, so that in order to maintain the calorific total approximately three slices of bread, butter and honey would have to be omitted. The protein would still remain adequate after this omission. The diet under discussion, as altered to satisfy the requirements for protein, now consists of five slices of bread, butter and honey, one quart of milk, two eggs. Consider next the need for the minerals, calcium and iron. The first is supplied adequately from the milk; iron, however, is present only in the eggs and it would take approximately a dozen to furnish 15 milligrams of iron. The deficit could be made up by substituting molasses for the honey on the bread; the calorific value and protein would not be affected.

The diet as developed to this point would be deficient in vitamins and roughage. The butter and eggs would supply enough vitamins A and D for an average adult; the milk and eggs would supply a fair measure of vitamins B_1 and B_2, but further additions would be advisable; vitamin C is almost entirely lacking. A generous salad of lettuce would yield the necessary C, add to the B_1 and B_2, and furnish roughage. Unless the dressing for the salad contained oil there would be no great alteration in calorific value. The diet for the day now considered as complete consists of the following: five slices of bread, butter and molasses, one quart of milk, two eggs and lettuce.

This collection of food will supply 2000 calories, slightly over two ounces of protein equivalent to that of meat, and sufficient minerals, vitamins and roughage for most adults. A greater requirement for fuel could be supplied by the addition of any type of food desired (even

candy), and its addition would not alter the basic requirements which have been fulfilled.

The assortment of foods given here is in no way intended to represent an especially desirable one; it was chosen merely by way of illustration. Similar calculations would apply to any other selection of foods. The necessary bulk could have been obtained equally well from cabbage, string beans, or any of the fruits; meat, if it contained blood, would replace the molasses and eggs as sources of iron.

Alcohol and Diet.

Ethyl alcohol can be burned in the body with the liberation of heat; for this reason alone it is sometimes technically classed as a food. The absorbed but unoxidized alcohol, unlike other foods, exerts a pharmacological action on the body, resulting in intoxication, which varies in degree with the amount of alcohol. It is for its drug action, not its food value, that alcohol is used. Nevertheless, the energy derived from alcohol consumed for its intoxicating effect may have a profound influence on the nutritive balance of the diet. The heat value of alcohol is high; 1 gram yields 7 kilocalories; an ounce, 200 kilocalories. Strong alcoholic beverages, such as whiskey and gin, contain from 40 to 50 per cent of alcohol; one ounce, a smaller amount than that usually taken at a single drink, yields 100 kilocalories and thus corresponds in heat value to three-quarters of a glass of milk, one large egg or an average-sized pat of butter. Alcohol belongs to the category of substances frequently referred to as "fattening"; this term has no precise meaning, for all foods are fattening if taken in excess of the energy requirements of the body. It is, however, loosely applied to concentrated foods of high energy content, like butter, olive oil, rich gravies, which are curtailed in reducing diets. From the dietary point of view the disadvantage of alcohol lies in the fact that it furnishes only calories; no protein, vitamins or minerals. The use of considerable quantities of alcohol at the expense of other foods may lead to dietary deficiency. Some of the deleterious physical effects of chronic alcoholism are now believed to arise from shortage of vitamins, minerals and protein rather than from the toxic effect of alcohol itself.

Methyl or wood alcohol, unlike ethyl, cannot be burned in the body.

Constancy of Body Weight.

The weight of an adult usually remains fairly constant over long periods. There are daily fluctuations of a few pounds which are due

mainly to the variations in the water content of the body; the drinking of a quart of water increases the weight two pounds, while an equal decrease follows the urination of a like amount of fluid; the loss by perspiration during vigorous exercise, such as a football game, may amount to four pounds, or even more. The weight may fall during a period of illness, but it is regained during convalescence. In some persons a gain or loss of weight accompanies change of environment or occupation; when the new conditions have become established the weight is again maintained at a constant level. The approximate constancy of the body's mass is indicated by the fact that nearly everyone can tell his own weight within a few pounds, even though he has not determined it on a balance for several months.

Aside from the large but temporary fluctuations due to variations in the water content, the weight of the adult body expresses the balance between energy expenditure and food intake. If the expenditure exceeds the intake, fat is removed from storage in the body and burned, and a decrease of weight occurs. If the food intake (expressed in heat units) exceeds the expenditure, fat is formed and stored, and the body gains weight. The nicety with which the food intake is automatically regulated is illustrated by the fact that if a man were to drink two glasses of milk a day in excess of the food actually needed to balance his energy expenditure, and if appetite and digestion permitted the addition, the gain in weight would, at the end of a year, amount to over twenty pounds. The reason that milk, unless deliberately forced, does not increase his weight is that he would automatically cut down on other food.

Regulation of Food Intake by Hunger and Appetite.

The expenditure of energy is variable from day to day and determines the need for fuel foods. The adjustment of the intake of fuel to the varying needs is accomplished through the sensation of hunger and appetite.

Hunger and appetite are distinct; the former is a basic function which definitely states need for food without discrimination; appetite is a refining influence and specifies the form of food chosen to satisfy the hunger.

Appetite is largely a mental quality; it depends essentially upon the pleasurable remembrance of an experience with some article of food which thereafter is appetizing inasmuch as the sight or smell or thought of it recalls the previous pleasurable sensations. The experiences

by which appetite or its opposite, the distaste for food, is established are not limited to any special feature of the food itself but extend to conditions surrounding the food—a point of extreme importance in cultivating a wide range of appetite in a child. It is possible for a child to acquire a taste for any article that can serve as food, as is witnessed in the diversity of racial food selections. It is also possible for the child to develop an active distaste for any food associated with an unpleasant experience, no matter how savory the food may seem to its friends or family. It is also possible to lose the appetite for some food, as may occur in the child who has gorged itself and sickened on some rich food like honey. In contrast to appetite, which indicates only desirable choice of food, hunger makes no such distinctions; hunger is the undifferentiated desire for food. Appetite may exist apart from hunger, as when one eats dainties merely to please the palate; likewise hunger may override appetite and force the taking of some food which, under ordinary circumstances, is distasteful or even nauseating.

Hunger establishes a total calorific value to which, over a period of time, the food intake must conform; the choice of food is left to the appetite. Consequently, some persons satisfy their needs on a small quantity of highly nutritious material, while others, equally hungry, eat a large quantity of food with a low calorific value. A meal made up, for example, of moderately fat roast beef, potatoes, spinach, lettuce, and bread and butter, can be eaten in two ways, both giving the same calorific total. One person may eat the meat with its fat, half the bread, and all the butter, and appear a "light eater," for he has left half the bread, the potatoes, the lettuce, and the spinach. Another person, a so-called "heavy eater," may leave only half the butter and all the fat of the beef; nevertheless, he has eaten no more in calories than the "light eater," for the lettuce and spinach contribute little fuel, and the extra potatoes and bread barely equal the fat of the beef and the extra butter.

When the appetite for some particularly tempting food exceeds the demands of hunger, and the amount taken is more than sufficient to balance the energy expenditure, the excess is compensated for by a decrease in the food intake at the next meal; otherwise the symptoms of surfeit and indigestion may develop. The lack of hunger at the time of the evening meal following a holiday dinner is a familiar phenomenon.

The average individual who eats three or more meals a day rarely experiences the fully developed sensation of hunger. If, however, he

omits meals or exercises with exceptional violence he will experience sensations which commence with a vague feeling of emptiness in the region of the stomach. If food is not obtained, the sensations increase to a dull ache or gnawing pain which is highly uncomfortable. During starvation the severe sensations of hunger last only for the first few days; thereafter they gradually decrease, and finally almost disappear. It is stated by those who have starved for long periods that although the hunger sensation is strong enough to cause discomfort, it is not painful enough to interfere seriously with work. Starvation cannot, therefore, be designated as actual suffering.

The sensations of hunger are associated with intermittent muscular contractions of the stomach; these contractions center the sensation specifically in the region of the stomach. But before this stage is reached, there usually occur certain accessory phenomena such as irritability, restlessness, a feeling of fatigue, weakness and vague discomfort which most individuals learn to interpret as a desire for food. The time at which the desire develops is largely conditioned by habit.

The volume of the food taken has an influence upon the immediate appeasing of hunger. A large portion of soup with a low food value satisfies hunger momentarily, but the sensation soon returns. A similar temporary stilling of hunger is accomplished by tightening the clothing so that the stomach is pressed upon. The hungry man pulls his belt tight to ease the gnawing pains, while the gourmand loosens his vest so that his appetite may be unhampered by satiation. Many women gain in weight for a period after having borne a child, and this is due, in part at least, to the relaxation of the abdominal muscles which then fail to exert one of the normal checking influences upon the intake of food; for the opposite reason tight lacing is sometimes followed by a loss in weight.

The hunger contractions of the stomach are stopped momentarily by the mere taking of food into the mouth; a hungry man finds solace in chewing non-nutrient substances such as leather. Contrariwise, the appetite of one who is recovering from an illness is fickle and hunger may disappear after a few mouthfuls of food.

The length of time that food stays in the stomach has an influence upon the time which will elapse before the recurrence of hunger; the sensation returns soon after a meal made up largely of carbohydrate, such as potatoes and crackers, but less quickly after one of meat, and only slowly after a meal high in fat. Fat gives what is called "richness" to the diet; it stays the longest in the stomach, and appeases the

hunger for a greater time than any other form of food. Although many factors appear to modify hunger, the effects are only temporary; the basic demand remains and the calorific need is balanced in the ensuing meals.

Starvation and Undernutrition.

Complete starvation, but with an adequate supply of water, can be tolerated without serious injury to health by a well-muscled and vigorous adult for about a month, but for a much shorter time by children, aged, and ill-conditioned individuals. During this period the body subsists on its store of fuel foods, fat, vitamins and minerals, and consumes its own protein. Loss of weight is the most evident change; but after four to ten days of starvation muscular strength diminishes and fatigue develops easily.

The belief that temporary fasting purifies and rejuvenates the body is ancient, but there is probably little benefit in the practice. Unintentional partial starvation resulting in malnutrition is common, particularly among children. It occurs whenever the diet is inadequate in fuel, protein, vitamins, or minerals. Such inadequacy may result from poverty and also from ignorance of dietary requirements.

Hunger unfortunately makes no specific demands for protein, vitamins and minerals necessary for growth, maintenance and repair of the body. The sedentary office worker requires as much of these food substances as does the laborer; the growing child even more. But their total food intake varies with their respective expenditures of energy. Upon the same choice of foods, therefore, the heavy worker fares the best, for any deficiency in essentials is accentuated in inverse proportions to the amount of food eaten. The smaller the total intake of food, the greater the discretion required in the choice of food.

Obesity and Reduction of Weight.

The adjustment of hunger to calorific needs is regulated basically by glands of internal secretion; consequently it may exhibit hereditary tendencies. Thus on a free choice of diet some individuals are thin, others are of so-called normal weight, and still others obese. Weight may vary in response to glandular changes such as those occurring during puberty and menopause. There is a natural tendency for most people to put on weight as they approach middle age; some, however, become obese in early life.

Overweight is a distinct handicap and obesity may be an actual

danger to health. Fat partially insulates the body against heat losses; as a result, fat individuals, although they may better resist hot surroundings than the thin, nevertheless sweat excessively. Their large consumption of water puts a burden on the heart. Any muscular exertion performed by the obese requires a greater expenditure of energy than for those of normal weight; they therefore fatigue more readily and tend to avoid exercise; in them also exertion puts a greater demand on the heart. The length of life of the obese is, on the average, shorter than for those of normal weight; they are also more prone to develop high arterial pressure and diabetes.

For these reasons reduction of weight is often suggested as a hygienic measure; more often it is dictated by fashion and frequently carried to harmful extremes. Weight can be reduced in two ways: (1) by increasing physical exertion, i.e., expending more calories but not increasing the intake of food; and (2) by maintaining the normal rate of exertion but decreasing the intake of food below the energy requirements of the body. The two are sometimes combined, but more often reduction is attempted by restricting the diet. Either form of reduction needs careful supervision; serious harm may result, particularly in middle life, from too strenuous exertion; and equally serious harm may follow from a curtailed intake of food which leads to inadequacy in protein, vitamins, and minerals. Reduction under all circumstances is a form of partial starvation.

Many obesity cures effect their reduction of weight by eliminating water but not consuming fat. Rapid loss of weight follows curtailment of fluid intake, profuse sweating induced by baths, and diarrhea caused by saline cathartics. If carried to extremes this form of reduction is highly dangerous; in any event it removes no fat from the body and the original weight returns when fluids are again taken. Fat cannot be sweated out of the body; attempts to rub it off succeed only to the extent of the energy expended in doing the rubbing.

The most logical form of dietary reduction consists in limiting the intake only of fats and carbohydrates. This may be safely done by eliminating all visible fat, such as butter and the fat of meats, and all foods consisting nearly entirely of carbohydrates, like candy and pastry. A study of the calorific values of food as given in Table VI will show the foods having the highest calorific values, the ones to be avoided. A calculation of the adequacy of the diet as described in this chapter will serve as a precaution in avoiding dietary deficiencies. Stringent dieting should be carried out only under the instructions of

a physician. It is unwise, and usually wholly unnecessary, to force partial starvation to a weight loss of more than one, at most two, pounds per week. Rapid reduction of weight is, under all circumstances, hazardous. It is likewise undesirable to restrict carbohydrates to any extreme degree; far less harm results from curtailment of fats. All drugs intended to reduce weight, such as thyroid extract or dinitrophenol, which increases the metabolic rate, are dangerous; any medicament offered as a cure for obesity, except on prescription of a physician for glandular disturbance, is either useless or harmful.

Time of Meals.

Definite criteria serve to establish the essential ingredients of a complete normal diet; disturbances of nutrition result if the body's requirements are not satisfied. On the other hand, there is no definite criterion to establish the time at which food is most advantageously taken. Consequently mealtime practices have become largely a matter of convention. The total daily bulk of food for man is large in contrast to that of the carnivorous animals, which eat usually once a day, but small in comparison to that of the herbivorous animals, which eat most of the time during their waking hours. It has become the general habit in civilized countries to divide the intake of food into three main portions, as the three meals of the day; sometimes these are supplemented by occasional snacks taken "between meals." The main meals are usually four to six hours apart. Physiological evidence points toward the belief that such periods are too long for the best efficiency of the body and that an interval not in excess of three hours is preferable. Such a regimen calls for the division of the total daily food intake into five portions: three main meals with two additional small ones, containing in part carbohydrates to be taken "between meals." This practice is now followed in many factories and offices with notable decrease in irritability and feeling of tiredness (which may appear as accessory phenomena of hunger, see page 118); in some cases factory production is definitely increased.

The widely held belief that eating between meals is harmful, especially for children, is derived, not from the time at which the food is eaten, but from the nature of the food selected. This same fact applies to the belief that a snack before bedtime is harmful; it is so only when the food selected, as is often the case, is difficult to digest. Milk, soup, cereals, bread and butter, fruit and kindred wholesome foods fill a definite place in between-meal feeding. All such small

meals, however, become a part of the daily total; they are subtracted from the "regular meals" and must be taken into consideration in calculation of the adequacy of the diet.

The belief that frequent feeding is injurious to the stomach has no foundation in fact. It is large, not frequent, meals that strain the stomach. Infants, individuals convalescing from illness and those with gastric ulcers are fed at frequent intervals and in small amounts to relieve the burden of digestion (see page 38).

Thirst.

The sensation of thirst controls the intake of fluids; it has no relation to hunger and does not arise from the stomach. Thirst is determined by the dryness of the mouth and pharynx. The salivary glands and the minute glands imbedded in the mucous membrane of the mouth and pharynx keep this area moist; the amount of fluid secreted is determined largely by the water content of the tissues of the body. Thirst may be produced independently of the supply of water in the body by any factor which dries out the mouth and throat, such as public speaking, breathing through the mouth, or strong emotion. On the other hand, thirst is momentarily relieved by rinsing the mouth with water, even if none is swallowed, or by increasing the flow of saliva by sucking a lemon.

CHAPTER VI

THE CIRCULATION AND ITS DISTURBANCES

UNICELLULAR ORGANISMS LIVE IMMERSED IN WATER. THROUGH THE SURFACE of the body they draw in food and oxygen dissolved in the water, and return carbon dioxide and other wastes. The presence of the water about these organisms is essential for their existence. Every active cell in the body of man is likewise bathed in fluid, lymph, which is derived from the blood. From it the cells take food and oxygen and to it they return carbon dioxide and solid waste in solution. The blood is a specialized ocean, a remnant of the primordial ocean in which all life was evolved. The blood is salty, for it has retained the salt in the same proportion as that of the ocean of which it was once a part. The large volume of stagnant fluid has been replaced in the body by a small volume kept in active circulation. At every round of the circulating blood its entire volume is spread out in a thin layer and exposed to the air in the lungs. From this air the blood absorbs oxygen while carbon dioxide diffuses from the blood to the air. Without this exchange of gases, energy expenditure is impossible.

Food is supplied to the blood from the digestive tract and from the body's labile stores of fat and sugar. The fluid of the blood is constantly renewed by a stream of water which flows into it from the liquid which we drink. Secretion of watery solutions through the skin and kidneys in the form of sweat and urine carries away the solid wastes, and maintains the normal volume of the fluid medium of the body.

Properties of Blood.

Blood is a red opaque fluid. When examined under the microscope it is seen to consist of a faintly yellow fluid, the plasma, in which float a great number of solid elements, the corpuscles, to which the opacity of blood is due. The corpuscles are of two types—the red corpuscles, and the so-called white corpuscles.

A few minutes after blood is drawn from the body it sets into a jelly-like mass. This clotting occurs through the formation of minute

threads of fibrin which separate from the plasma. The net of fibrin permeates the fluid and incloses in its meshes the red and white corpuscles. The fibrin gradually shrinks, the corpuscles are restrained in the net, and a fluid is pressed out. This fluid is called serum and is plasma from which fibrin has separated during clotting. Serum does not clot.

The Quantity of Blood in the Body and Its Constancy.

The blood makes up about 8.5 per cent of the weight of the body. Thus a man weighing 154 pounds (70 kilograms) has approximately 13 pounds or 6.5 quarts (or liters) of blood. The normal volume of the blood is maintained with great persistency in spite of various factors which tend to alter it. The tissues of the body act as an enormous reservoir to take up or give back water to the blood to equalize its volume. When water is drunk it passes through the walls of the intestines into the blood; but the volume of the blood is altered only momentarily, for as the water is absorbed a like quantity passes from the blood to the tissues. Water is constantly formed in the tissues from the oxidation of fat; this, in fact, is the only source of supply for animals, such as the woodchuck, during hibernation. The kidneys continually secrete fluid which is taken from the blood; but this loss, or one from perspiration or any other secretion, is made up by a return of water from the tissues. When the reserve of fluid in the tissues has been reduced to a certain level, the sensation of thirst is aroused.

In maintaining the blood at a uniform volume the water content of the tissues fluctuates. The rate at which urine is secreted and the sensation of thirst act together to minimize these fluctuations and to maintain a normal content of water in the tissues. Contrariwise, when the water content of the tissues is raised considerably, as is the case when a quantity of water is drunk at a time when there is no particular demand for water, the secretion of urine is increased. When the content of water in the tissues is lowered by excessive perspiration, the secretion of urine is diminished.

Unlike the water and dissolved substances of the blood, the red corpuscles do not pass in and out of the capillary blood vessels. The number of corpuscles in a cubic millimeter of blood taken from any individual remains fairly constant over long periods. This fact is an indication of the uniform volume at which the blood is maintained. Even after a severe hemorrhage the volume of blood is restored to normal in a very short time, although it may be several weeks or

months before the normal number of red blood corpuscles is recovered. A severe hemorrhage induces great thirst; the wounded man cries for water.

Up to half a century ago the belief persisted that the volume of blood is increased in many disorders and that this supposititious condition of plethora induced many ill effects. It was the practice to bleed people for nearly every sort of disorder. At one time bleeding was the main occupation of the physician. Monks were bled regularly even when well. Perhaps a high arterial pressure was in those days mistaken for a too large quantity of blood. Bleeding is now rarely resorted to; nevertheless, it is occasionally practiced as a rapid means of temporarily lowering a critically high arterial pressure and of relieving the burden on the heart in congestive heart failure.

In water starvation or in the water depletion of severe diarrhea, such as that of Asiatic cholera, the severity of the condition may drain the tissues sufficiently to decrease the volume of the blood. Death may result from this dehydration. If the thirst is satisfied or, in the case of cholera, if adequate water is supplied intravenously, the blood volume is quickly restored to normal.

The volume of blood in the body is not necessarily the amount actually in circulation. Certain organs, particularly the spleen,[1] located in the left side of the abdomen, and also the liver, are capable of distending and holding blood in reserve. When needed, as in violent exercise, the spleen squeezes down, forcing out the blood and adding it to that in circulation.

Red Blood Corpuscles.

The red corpuscles are thin, circular disks, slightly biconcave. Their diameter is between 7 and 8 microns, or 0.00028 to 0.00032 of an inch, and their thickness is one-fifth as much. One cubic millimeter of normal human blood contains about 5,000,000 red corpuscles; a cubic inch would contain nearly 16,000 times as many. The total surface of the red blood corpuscles in 1 cubic millimeter of the blood is 640 square millimeters, or about 1 square inch. The body contains approximately 6.5 liters of blood; the total number of red corpuscles, therefore, is some 30,000,000,000,000 and their total surface about 4000 square meters, or

[1] Life will continue after the removal of the spleen; it is not therefore a vital organ, but it plays an important rôle in protection against oxygen shortage as in high altitudes and also in heart disease.

approximately 1 acre. The surface of a man's body is 2 square meters or less. The red blood corpuscles carry oxygen; the whole of their enormous surface is exposed for free diffusion of gases from and into the air in the lungs at each round of the circulation.

The red blood corpuscles consist of a delicate sac or sponge containing red material known as hemoglobin. Hemoglobin is a protein compound containing iron; it is by means of this iron that it performs its function. When exposed to the air hemoglobin absorbs oxygen and oxyhemoglobin is formed. This reaction occurs as the blood passes through the lungs. When the blood reaches the tissues a part of the oxygen diffuses out and is consumed in the activities of the cells. In consequence of this loss of oxygen some of the oxyhemoglobin is reduced to hemoglobin. Oxyhemoglobin has a bright vermilion color; hemoglobin from which oxygen has been withdrawn is a deep purple. The blood in the arteries is bright red[1] and so is that shed from a wound, for the exposure to the air converts any hemoglobin present into oxyhemoglobin. The blood in the veins has been passed through the tissues and therefore contains less oxygen. The bluish color of this blood is apparent in those veins which run just beneath the skin, as on the back of the hand or on the inner surface of the elbow.

About two-fifths of the volume of blood is made up of red corpuscles. The corpuscles are heavier than the plasma or serum, and when blood is allowed to stand in a vessel and clotting is prevented, they settle to the bottom. The rate at which they settle, the so-called sedimentation rate, is increased during certain diseases, such as rheumatic fever, and is used as a diagnostic measure.

The red blood corpuscles are sensitive to a decrease in osmotic pressure. The blood has an osmotic pressure equivalent to about 0.9 of one per cent of sodium chloride. If distilled water is added to the blood, the corpuscles are first distended and then ruptured and the hemoglobin is discharged. Blood is said to be "laked" when the hemoglobin has been thus set free from the corpuscles. This laking, or hemolysis, may occur in the body from infections as by the hemolytic streptococcus, or from poisoning with snake and spider venom. Hemoglobin freed in the circulating blood is removed by the kidneys

[1] This is true only of the greater circulation, i.e., that supplied by the left side of the heart. In the lesser circulation from the right side of the heart through the lungs these color relations are reversed; the blood flowing to the lungs in arteries is bluish; on aeration in the lungs it absorbs oxygen so that the veins carry away vermilion-colored blood.

and is eliminated in the urine. It gives the urine a blackish color. Thus a severe type of malaria occurring in Africa, in which part of the blood is laked, has been named from the color of the urine, "black-water" fever.

Formation and Destruction of the Red Blood Corpuscles.

The red blood corpuscles are formed in the red marrow of the bones. At birth the central spongy portion of all bones is filled with red marrow, but with subsequent growth much is replaced by fat, yellow marrow. In an adult most of the red marrow is in the ribs, breastbone and bones of the pelvis. The red marrow is a highly specialized and well-regulated organ having a total volume nearly as great as that of the liver. This marrow is permeated by large capillaries of peculiar construction; similar capillaries are found in the spleen and liver; all are part of the so-called reticulo-endothelial system from which the red and white blood cells originate. In the formation of red cells some of the capillaries in the red marrow are temporarily shut off from the circulation. The red corpuscles develop from the cells lining the walls of the minute pockets thus formed. At first, like other cells of the body, they contain a central mass known as a nucleus, which is essential for cell multiplication. As they mature, hemoglobin fills their substance and this nucleus is lost and with it, the ability to multiply. When the red cells are fully developed, the capillaries in the bone marrow containing them open up and release them into the circulating blood.

In the circulation the red cells are subject to rough treatment; they disintegrate after a length of time estimated at about thirty days. Thus some 3 per cent of the red cells are destroyed daily or, roughly, 700,000,000 each minute. Part of the iron from the hemoglobin of the disintegrated red cells is carried away in the bile; the remainder is returned to the red marrow for the formation of new corpuscles. The constancy with which the number of red cells in the blood is maintained indicates the nicety with which the rate of their formation in the marrow is regulated to correspond to their rate of destruction.

Although 3 per cent of the red blood corpuscles are destroyed each day, this normal process is different from a hemorrhage involving an equivalent loss. In the case of the hemorrhage the iron of the hemoglobin is not salvaged but is lost. It can be replaced only by an extra amount of iron taken in the food or as a medicament.

Anemia.

Red cells cannot be formed without iron; the body has no great store of this substance and the loss through the liver, though small, is continuous. It must be replaced by iron taken in the food. If iron is not supplied in the diet a deficit develops and after a time the normal formation of corpuscles is prevented. As the destruction of corpuscles continues without interruption, the number of red cells, and often their content of hemoglobin as well, is decreased. This condition, whether resulting from lack of iron in the diet or from other causes, is known as anemia.

The number of red cells in the blood, the so-called red count, can be determined in a drop of blood drawn from a needle prick, after it is measured, diluted, and placed in an especially designed counting chamber under a microscope. The amount of hemoglobin is ordinarily estimated by putting a drop of blood on a piece of blotting paper and comparing its red to those on a chart showing the colors of blood with different amounts of hemoglobin. The red cell count is expressed as the number of cells per cubic millimeter of blood; the hemoglobin, as the percentage of the normal; thus a particular blood examined might have 4,900,000 red cells with 90 per cent hemoglobin.

The blood in anemia is not as red as normal blood; one of the symptoms of anemia is pallor of the skin and mucous membranes, particularly of the conjunctiva of the eye. All skin pallor is not, however, due to anemia. The normal color of the skin is determined in part by its pigments and in part by the quality and quantity of blood which it contains. The pallor of fainting is due to lack of blood in the vessels of the skin, and not to anemia. Certain races, such as the Polish, have a thick but only slightly pigmented skin; consequently they show little color in their cheeks. Other races, such as the Germanic, have, for opposite reasons, a pink skin. Persons who live under poor hygienic conditions often appear pale, although they may not have anemia. The combination of poor food and dark or poorly lighted quarters produces a pallor of this type—the so-called prison pallor.

Anemia may be caused either by an excessive destruction or by an insufficient formation of red cells. Thus hemorrhage and deprivation of iron are both followed by anemia, but from opposite causes. A loss of red cells acts as a stimulus to the red marrow to form new cells at a more rapid rate. Thus frequent hemorrhages, such as from excessive menstruation, bleeding hemorrhoids, or repeated nosebleed, may be compensated for a long time by an increase in production of

red cells. In fact, the production may at times overcompensate the loss of blood. If, however, the hemorrhages are severe or often repeated, the reparative processes become exhausted, either from lack of iron or from fundamental changes in the bone marrow, and anemia develops.

Anemia occurs in many acute and chronic infections and is a marked feature in poisoning by certain chemical substances, particularly benzol, nitrobenzene, aniline and lead.

Usually the only symptoms that develop from anemia are those that arise from the lack of hemoglobin in the blood; the blood is unable to carry the normal amount of oxygen; breathlessness and fatigue follow slight exertion. There is one disease classed as anemia in which the symptoms are much more severe; it is the so-called pernicious anemia. There is a decrease in the number of red cells, and with it disturbance in the nervous system which leads to loss of sensation and paralysis, and in the alimentary tract which leads to lack of hydrochloric acid in the gastric juice and soreness of the tongue. Formerly in pernicious anemia all efforts to restore the red cells to normal failed; after a prolonged course the decrease was invariably fatal. Now it can be controlled and life saved.

The study of pernicious anemia which led to its remedy has revealed much additional knowledge concerning the formation of red cells in red marrow. These cells can develop only when there is present in the blood a small amount of an anti-anemia substance of an as yet unknown nature. This substance is normally derived from some element in the food, but it must first be liberated by the action of an enzyme in the stomach. Any excess over immediate needs is stored in the liver. Neither the food element nor the enzyme has been fully identified, but the former is believed to be closely allied in nature to vitamin B_2; it is present in most of the foods, particularly meats, containing this vitamin.

Anemia may result from a diet deficient in this particular food element even in the presence of adequate iron; it may also develop when the enzyme necessary to liberate the anti-anemia substance from food is lacking in the secretions of the stomach. It is this gastric deficiency which is the cause of pernicious anemia. The disease may be controlled by adding liver to the diet or administering an extract of liver, both of which supply the fully formed anti-anemia substance; it may also be controlled by administering the enzyme needed to liber-

ate the substance from food. The enzyme is obtained for this purpose from the tissue of the pig's stomach.

Polycythemia.

A marked increase above the normal in the number of red cells (i. e., over 6,000,000 per cubic millimeter) is known as polycythemia. An apparent polycythemia is produced when the volume of blood is decreased as in water starvation or Asiatic cholera, and its elements are thus concentrated. A true polycythemia occurs when there is a disturbance in the balance between red cell destruction and formation, with the latter in preponderance. The number of red cells may be increased from the normal 5,000,000 to as many as 10,000,000 per cubic millimeter; in exceptional cases, to 15,000,000.

In some instances polycythemia is an adaptation of the body to a particular environment, such, for example, as high altitudes where the air is rarefied. When the blood is exposed in the lungs to a decreased pressure of oxygen the concentration of oxygen in the blood is reduced. Under these conditions a compensatory polycythemia gradually develops; with the increased power to carry oxygen the blood is able to absorb the normal amount. In the high Andes red cell counts of 7,000,000 or 8,000,000 per cubic millimeter are normal. The adaptive increase or decrease to change in altitude is not immediate, but develops in the course of several weeks. Prolonged exposure to small amounts of carbon monoxide produces a polycythemia in a manner similar to high altitude. Blood counts made on men who work in garages or about blast furnaces have, in some instances, shown 7,000,000 or 8,000,000 red cells per cubic millimeter.

Contrary to the claims made for some proprietary medicines, taking large amounts of iron does not increase the number of red cells in the blood unless anemia exists. Persons who have a polycythemia do not feel exhilarated, nor are they more than usually resistant to fatigue. In the environment which causes the polycythemia, however, they may be able to maintain activities which would be impossible for a person with a normal red cell count.

White Blood Corpuscles and Infection.

The white blood cells or leucocytes can be counted in much the same manner as the red; their number is less, ranging under normal conditions from 5000 to 9000 per cubic millimeter; it is also more variable and may, under certain conditions, rise to many times these values.

Digestion, sleep, exercise, pain, and other conditions may temporarily alter the number of white cells, but the most important factor is infection, so much so that the white count is a decisive feature in the diagnosis of many diseases.

The physician not only counts the number of white cells but also estimates the proportion of the various kinds present. To do this he spreads a thin film of blood on a glass slide, dries it, stains it with dyes and examines it under the microscope. The two most numerous types of white cells are called granulocytes and the lymphocytes. The granulocytes are thus named because their substances contain small granules; they normally constitute 60 to 70 per cent of the total number of white cells. There are large and small lymphocytes and each sort is composed almost entirely of a nucleus; they constitute 20 to 28 per cent of the white cells. The granulocytes are formed in the red bone marrow; the lymphocytes, in the lymph glands (see page 183).

The white blood cells can change their shapes; they are capable of independent movement and can even force their way through the walls of capillary blood vessels and migrate between the cells of tissues. They are, in fact, virtually independent unicellular organisms living in the blood. The white cells serve important functions in the transportation of materials in the body, especially in carrying fat globules through the walls of the intestinal tract following digestion. They also secrete digestive fluids by which dead tissues of the body are broken down for removal. But their most striking characteristic is shown in relation to bacterial infection. The granulocytes are phogocytic—that is, they are cell eaters. Following infection they engulf, literally eat, and destroy bacteria. When bacteria infect the body they liberate certain chemical substances which pass into the blood and serve to attract the white cells. In response, the production of white cells is increased and the number in the blood, the "white count," mounts from the normal 6000 or 9000 to 15,000, 25,000, or even more.[1] This increase is known as leucocytosis. If the bacterial infection is local, the reinforcement of white cells is called to the particular spot at which it is needed. Thus when bacteria enter the tissues through a break in the skin, white corpuscles congregate there, work their way through the walls of the blood vessels, and engulf and destroy the bacteria. The white corpuscles also die. As the accumulation of dead

[1] In very severe infections the number of white cells may be diminished instead of increased; this is an unfavorable sign. The number may also decrease as a regular occurrence in certain less serious infections, notably influenza.

corpuscles increases, a pocket is formed in the tissue at the point of infection. This pocket either breaks through the skin from the pressure of the accumulation, or more often is opened by an instrument. The thick liquid which pours out from the opening is composed of dead corpuscles. It is known as pus.

The formation of pus is always a sign of infection; but all infections are not followed by the formation of pus. The white corpuscles do not oppose effectively all forms of disease-producing bacteria. Thus infection with some of the most dangerous, such as the bacillus of tuberculosis and certain of the streptococci which are, *par excellence*, the organisms causing septicemia or "blood poisoning," does not result in pus formation.

The production of white cells in bone marrow and lymph glands is occasionally subject to disturbances which constitute definite diseases. Of these the least serious is one called infectious mononucleosis. It occurs mainly in young individuals and is spread by contact. There is fever, the lymph glands throughout the body enlarge, and in the blood one variety of white cells, the monocytes, are greatly increased in number. Recovery always occurs within a few weeks, but the enlargement of the lymph glands may persist much longer. The infective agent causing the disease has not been discovered.

Another disease of white cell formation called leukemia is far more serious. In this disease the number of white cells is enormously increased, sometimes exceeding 100,000 in a cubic millimeter. In young people leukemia may be acute, speedily resulting in death; in older people it tends to be more chronic, lasting for several years before death results. The cause of leukemia has not yet been established with certainty, but many indications support the belief that in some ways it is similar to cancer—in this case, a cancer-like growth of the tissues from which the white cells are formed. This has been shown to be so for a disease somewhat resembling leukemia and known as Hodgkin's disease.

Still another serious disease of white cell formation is called agranulocytosis, a decrease in the number of granule-bearing white cells. It is not a common disease, and is one that occurs more frequently in women than in men; it is usually fatal. The disease appears to be an infection, but the point that brings it into particular prominence is that certain remedies intended to relieve pain seem to increase the predisposition to acquire it. The substance mainly implicated is amido-

pyrene, a common ingredient of proprietary medicines sold to relieve headache and insomnia. Aspirin offers no danger in this direction.

Coagulation of the Blood.

After any slight injury involving the cutting or tearing of some of the smaller blood vessels, the blood coagulates at the point of its escape; the clot seals the wound and stops the bleeding. If the blood did not coagulate, every slight wound would be followed by a continuing and finally fatal hemorrhage. When a large artery is cut, coagulation is not sufficient to check the hemorrhage, for the rapidity of the flow prevents the formation of a clot over the wound. Under these circumstances the hemorrhage is usually controlled by compressing the artery and shutting off the flow of blood, as with a tourniquet.

The essential of clotting consists in the precipitation of a protein in the plasma. The precipitate, fibrin, separates as fine threads which entangle the corpuscles, thus forming a barrier through which fluids cannot pass. The complicated process of clotting is initiated by a chemical substance of as yet unidentified composition, which is present in the juices of injured tissue and also in the blood platelets from which it is discharged when the platelets disintegrate, as they do on exposure to air. The blood platelets are minute bits of material broken off from cells in the red marrow and circulated in the blood. The number of platelets in a cubic millimeter of blood is variable, but usually exceeds 200,000. If the number is considerably lower, clotting is slowed and may even fail to occur.

The activating substance liberated from the platelets exerts an action upon a fat-like material of the blood called prothrombin, with the result that prothrombin is changed to thrombin. This alteration can occur only in the presence of calcium which is a normal constituent of the blood. The thrombin formed acts in turn upon a protein of the blood known as fibrinogen, converting it into fibrin. Fibrin constitutes the threads of the clot.

In the blood there are substances in small amounts which tend to prevent clotting; they are formed in the liver. Their presence probably prevents the clotting which might result from the slow and normal disintegration of platelets in the circulating blood. During menstruation there are similar substances secreted in greater abundance from the wall of the uterus to prevent the menstrual blood from clotting excessively.

Hemophilia.

The sequence of events leading up to the formation of fibrin requires some minutes for completion, normally three to six. This period, often determined on blood drawn from a needle prick before surgical operations are undertaken, is known as the coagulation time. In some diseases the coagulation time is lengthened so that a hemorrhage persists and is difficult to check. This condition usually disappears with recovery from the disease. There are some persons whose blood at all times coagulates with abnormal slowness. They are called "bleeders." Their disease, hemophilia, is hereditary, but in a peculiar way; it affects only male members of the family, but is transmitted only through females. Thus the sister of a man afflicted with hemophilia, without herself having the disease, may transmit it to her son. Usually the disease is not strongly manifest in infancy; it becomes apparent only after childhood is reached. Most individuals suffering from hemophilia manage to survive small injuries, but they may succumb to one in which a small artery is damaged, as occurs in the extraction of a tooth.

In hemophilia the constituents of the blood are present in normal amounts; the delay in clotting is apparently due to a lack of fragility in the blood platelets; they do not disintegrate in a normal manner to liberate the material needed to initiate clotting.

Hemophilia is one of the so-called hemorrhagic diseases; another is known as purpura. In purpura the blood may clot normally, but the smaller blood vessels become abnormally fragile; they rupture and as a result small hemorrhages occur in the tissues. Similar subcutaneous hemorrhages may occur in a normal individual as the result of a severe blow. The bruise then appears as a "black and blue" spot. Such a hemorrhage is particularly abundant when it occurs about the eye because of the laxness of the tissues there. There is great individual difference in the fragility of the small blood vessels; some persons mark little from bruises, while others are so sensitive that the increased pressure of blood caused by an effort to blow hard is followed by small red spots on the face and neck. In those suffering from purpura the hemorrhage into the tissues occurs with slight external pressure or even with none. In the disease scurvy purpuric hemorrhages occur, particularly in the gums and joints. In other diseases such as measles and smallpox, and also in poisoning from benzol, there is both fragility of the small blood vessels and delay in clotting time. Many small hemorrhages may then occur under the skin, and show as the eruptions that characterize the disease.

Thrombosis and Embolism.

Occasionally a clot forms within the blood vessels without any evident injury having occurred. This unusual occurrence is known as thrombosis; the clot that forms is known as a thrombus. Any condition that slows the flow of blood in a vessel or that injures or roughens the walls of the vessel predisposes to thrombosis. Thus varicose veins in the legs or about the rectum, as hemorrhoids, are often the seat of thrombosis because the abnormal widening of the vessels slows the flow of blood. Thrombosis may also occur in arteries that have become hardened, that is, sclerosed, because in this condition the walls of the vessels are roughened (see page 150). Likewise thrombosis may follow an injury such as a blow on the leg or the pressure of a tight bandage which injures the underlying vessels. The presence of infection greatly increases the tendency to thrombosis, and often the bacterial action centers in the thrombus. This is the case in the disease milk leg, which is an infected thrombus in an inflamed vein of the leg, so named because of its special prevalence after childbirth. The inflammation in a vein from this or any other cause is known as phlebitis.

Thrombosis occurring in an artery shuts off, partially or completely, the flow of blood to the organ which the artery normally supplies. The seriousness of the consequences depends upon the organ affected. In the leg or arm the curtailment in the flow is followed by pain and coldness. In time, the small communicating branch vessels expand and form an adequate detour for a flow of blood about the thrombus; the circulation is then restored. Thrombosis occurring in an artery of the heart, so-called coronary thrombosis, may result in death; and the thrombosis of an artery of the brain is the cause of one kind of apoplexy.

Thrombosis in a vein, whether in the leg or any other part of the body, except the hemorrhoidal vessels of the rectum, may have serious consequences quite aside from the local effects. A piece of the thrombus may be broken off and carried away in the stream of blood. A thrombus which has thus broken free is known as an embolus. From the veins the clot may reach the heart and from there be carried to the lungs, obstructing the flow of blood. This serious condition is known as pulmonary or lung embolism. It is to prevent the occurrence of embolism that every precaution is taken to keep those afflicted with thrombosis as still as possible until the thrombus has grown firmly in place in the blood vessel.

The term embolus is not limited to a floating piece of blood clot, but is applied to any foreign substance which enters the blood and may obstruct its flow. It is possible for an embolus of air to occur; the air may enter an open vein in a wound in the neck. The symptoms of caisson disease, which sometimes affects divers and workers in compressed air, arise from emboli of nitrogen gas which form in the blood. The bubbles plug the capillaries; and if the gas collects in the heart in considerable quantities death occurs, for the heart valves do not operate except in a liquid, and the gas trapped in the heart keeps the blood from entering.

Transfusion of Blood.

Blood of one man may, under suitable conditions, be transferred to the vessels of another man. Such transfusion is performed for severe anemia following hemorrhage or resulting from an infection, and also for the treatment of hemophilia or other hemorrhagic diseases. The red cells of the transfused blood live no longer in the recipient than in the donor. Except in hemophilia, in which the benefit derived is not from the red cells but from other elements in the blood, transfusion is a measure designed to tide over an emergency and to maintain life until the normal reparative processes have time to operate.

The blood of an animal cannot be transfused into man, for the bloods of different species frequently react so that the red cells either lake or clump together, forming minute emboli. In certain instances even human bloods may react in these ways. Fortunately the presence or absence of harmful reactions can be determined before transfusion is carried out by mixing a few drops of the two bloods and examining them under a microscope. Bloods are classified in respect to the interactions thus determined into four types, usually designated by Roman numbers but sometimes by the letters O, A, B, and AB. The serum of the blood donor does not greatly affect the corpuscles of the recipient; it is the corpuscles of the donor and the serum of the recipient that react. Table IX shows by letter designations the peculiarities of the four types of blood.

The a and b of the serum represent the presence of substances which react with the corresponding A and B of corpuscles to cause clumping of the cells, agglutination. The symbols o and O show that such materials are absent. Thus, if corpuscles of type II were transfused into an individual of type I, the a element of the recipient's serum would react disastrously with the A element of the donor's corpuscles. A man with

TABLE IX.—BLOOD TYPES

Type	Serum	Corpuscles
I or O	ab	O
II or A	b	A
III or B	a	B
IV or AB	o	AB

blood of type I can be transfused only from a donor of type I, whereas, theoretically, he could, because of the lack of agglutinating material in his own corpuscles (symbol O) act as donor for recipients with any type of blood. Except in emergencies, transfusion is performed only between individuals of the same blood type.

In the western races more than 80 per cent of all individuals show blood of types I and II; in eastern races the preponderance is in the other types. Blood types are determined by heredity and follow the Mendelian law. Thus, subject to sharp limitations, blood grouping has been used to assist in establishing the parentage of children. The method operates mainly for exclusion; thus a child with a certain blood type has as his parents only individuals whose bloods in combination are capable of yielding this type. On this basis the number of possible parents on either side runs into many millions. On the other hand, an alleged individual whose blood could not provide the necessary part of the proper combination is proved not to be the parent.

Circulation of the Blood.

The blood is the vehicle for the transportation of substances within the body. It can perform its function only when it is kept in motion. The heart supplies the motive force and the blood vessels form the channels which direct its course.

The heart is a muscular bulb divided longitudinally by a partition into what are virtually two hearts. On relaxation these chambers are distended by an inflow of blood from the veins. When they contract this blood is forced out. An arrangement of check valves directs the stream so that the blood entering from one set of vessels is ejected into another set under increased pressure. In other words, the heart is a pump.

The chambers of the heart which give pressure to the blood stream, and which are guarded by valves, are known as the ventricles. Above

each ventricle is a distensible chamber, an integral part of the heart, in which the blood collects to fill the ventricles. These chambers are known as auricles.

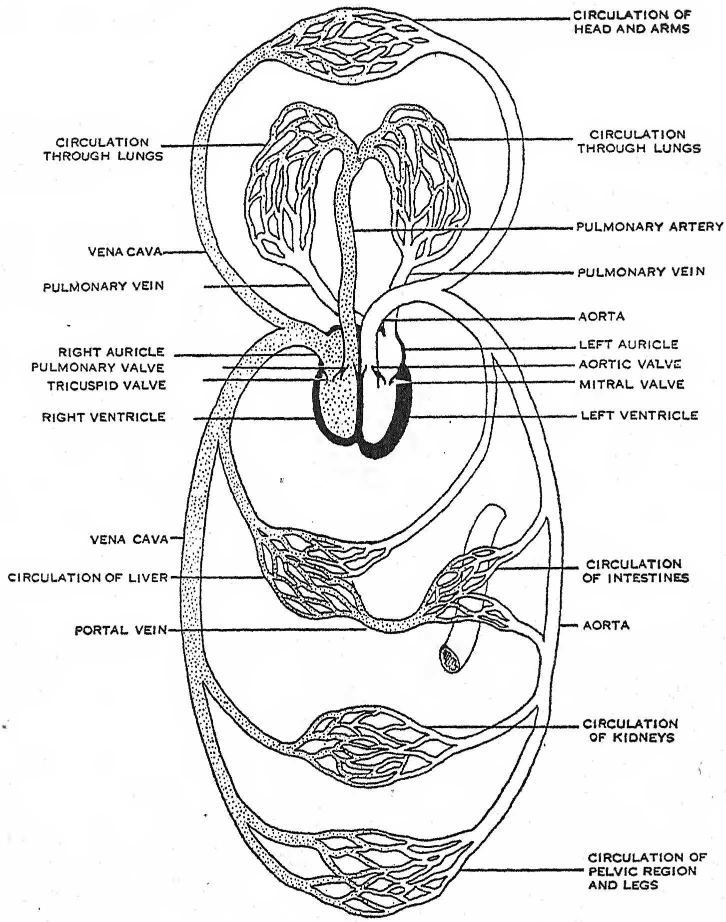


Figure 14. Course of the Circulation.
The shaded area indicates blood in the venous condition.

In the veins the blood flows toward the heart, and the pressure in these vessels is low. In the arteries the blood flows from the heart, and the pressure is high. The arteries form the distributing system for the blood. The veins collect it and carry it back to the heart. The blood

within the veins and arteries does not come into direct contact with the cells of the tissues of the body. No exchange of substances occurs through their walls. The arteries communicate with the veins through the capillaries. Capillaries are very minute tubes, sometimes barely large enough to allow the corpuscles to pass in a single file. The walls of the capillaries are exceedingly thin. An active exchange of material takes place through them between the blood and the cells of the tissues. A closed system is formed by the heart, the arteries, capillaries, and veins. Within these vessels is inclosed all of the blood in the body. Through this system the blood is circulated by the pumping action of the heart.

The course through which the blood moves was first established in 1628 by William Harvey. By two large veins, the venae cavae, one from the head and arms, the other from the abdomen and legs, the blood is poured into the right auricle. It flows from there through a valve into the right ventricle. By the contraction of the right ventricle the blood is forced through a second valve into the pulmonary artery, which goes to the lungs. From the pulmonary artery the blood flows through the capillaries of the lungs and is thus aerated. Leaving the capillaries, it is collected in the pulmonary veins, from which it goes to the left auricle. From the left auricle the blood flows into the left ventricle. From there it is forced into the great artery of the body, the aorta. Arteries branch from the aorta and pass to every part of the body. They terminate in capillaries permeating every tissue. From the capillaries the blood is collected into venules which enter large veins until the stream is finally gathered into the venae cavae. Thus the round of the circulation consists in the blood being pumped by the right side of the heart through the lesser circulation of the lungs to the left side of the heart, and by the left side through the greater circulation to the tissues of the body and back again to the right side of the heart.

The course of the circulation described here is that of the postnatal, hence air-breathing, human being and not that of the unborn child which derives its oxygen from its mother and so does not use its lungs. The unborn child has no active lesser circulation. The necessary vessels are in place, but the blood is shunted directly from the right side of the heart to the left through an opening in the partition that later separates the two; a special vessel also connects the pulmonary artery and the aorta and so further short-circuits the lungs. Special vessels branching from the aorta and venae cavae go out along the umbilical cord to the placenta attached to the wall of the mother's uterus.

Through capillaries these vessels form a circuit from which the child's blood picks up from the mother's blood food and oxygen and returns waste. With the establishment of respiration at birth, the openings from the right to the left side of the heart are closed off, leaving the passage through the lungs as the only course for the blood to follow. The lesser circulation is thus established. In rare instances this transition is incomplete and a portion of the blood continues to pass directly from the right to the left side of the heart. In this abnormality, which is called congenital heart disease, the mingling of the venous and arterial bloods may give the skin a dusky blue color, cyanosis. Cyanosis may appear from any cause that lowers the oxygen content of the arterial blood, as in severe heart disease and other forms of asphyxiation.

Structure of Blood Vessels.

When a large artery is cut, the blood escapes under such pressure that if a vertical glass tube is inserted the column will rise to a height of six feet or more. The first experiment to demonstrate this fact was made in 1732 by Stephen Hales, a preacher, who performed it on a horse. The column in the tube pulsates. This pulsation of the pressure in the arteries can be felt by placing the finger over those arteries which run near to the surface, as in the wrist, neck, or temple. When a vein is cut the blood wells out in a continuous stream under no evident pressure. It does not pulsate. The superficial veins on the back of the hands offer no appreciable resistance to compression when a finger is placed upon them. A pink color is imparted to the skin by the blood which flows through the capillaries; that the pressure of the blood in the capillaries is slight can be made evident from the small force which it is necessary to apply to the surface of a finger nail or on an area of the skin to blanch it by driving out the blood of the capillaries.

The structure of the blood vessels corresponds to their function. The arteries are strong elastic tubes sufficiently firm to hold their shape when they are cut and emptied of blood. The elasticity of the arteries tends to minimize the fluctuations in the blood pressure arising from the intermittent action of the heart. Their action is analogous in principle to the air cylinder on a water pump. During the stroke or systole of the heart the larger arteries are stretched by the blood forced into them. During the relaxation of the heart they recoil, converting this potential energy into dynamic energy, and thus spreading the force of the stroke over the time between beats, or diastole.

The veins are of lighter construction than are the arteries. When

exposed and emptied of blood they collapse into thin ribbons. The size of a vein is varied by the pressure of the blood within it. This variation is apparent in the veins which run near the skin. Those on the wrist or forearm swell when the blood is dammed back by tightly grasping the arm. The veins in the hand are seen to fill and empty when the hand is held down and then lifted above the shoulder. Many of the veins are equipped with valves placed at irregular intervals. These valves are so arranged that the flow toward the heart is unimpeded, but flow back toward the hands or feet is checked. The valves thus prevent the blood in the veins from running into branches which may be momentarily at a lower pressure than the main vein. They also make possible an acceleration of the flow of blood through the compressing action of moving muscles. Thus movements of the legs help the return of the venous blood.

The capillaries are such exceedingly minute tubes that several thousand may perforate a piece of tissue no larger in diameter than a common pin. They are very short, averaging about 0.5 mm. (0.02 inch) in length. Their diameter, like that of the veins, varies with the pressure of the blood within them. Their walls are made up of a single layer of thin cells. The capillaries permeate the tissues and thus supply the cells.

Regulation of Blood Flow.

The supply of blood to any organ or tissue can be augmented in two ways: (1) by increasing the pressure of the blood in the arteries, and (2) by increasing the caliber of the arteries. The arteries have a layer of muscle fibers in their walls. These muscle fibers are supplied with nerves of two sorts; one set of nerves brings impulses which cause the fibers to contract and thus constrict the artery and lessen the supply of blood; the other set brings impulses which cause the fibers to relax, thus enlarging the artery and increasing the flow of blood. The size of the artery at any time is determined by the interaction of these two nervous influences. These so-called vasomotor nerves are mainly in what is known as the sympathetic nervous system. They are regulated and their action is coordinated by nerve centers in the brain so that when one group of vessels relaxes another group is constricted. By this means the resistance to the flow of blood is kept constant so that the general pressure of the blood is maintained. When the arms or legs are exercised the vessels supplying the muscles with blood are dilated; at the same time those to the abdominal organs are constricted. The flow of blood is thus diverted to the exercised part. The nerves

which go to the arteries are bilateral in their action, so that when only one arm is exercised the opposite and unexercised arm also receives an extra supply of blood.

The constriction and dilatation of the vessels which supply the skin of the face are often quite apparent. Blushing is caused by the dilatation of the vessels; the pallor which accompanies fear or other strong emotions is due to constriction. The vessels of the skin also become dilated as a result of exercise or hot surroundings. In consequence of the increased flow of blood the skin becomes warmer; more heat is thus dissipated from the body. A hot bath or violent exercise soon after meals may cause indigestion through the compensatory constriction of the abdominal vessels accompanying the dilatation of the vessels in the skin. Cold tends to cause the vessels in the skin to contract, but exposed parts like the ears may redden because the constrictor nerves are paralyzed by the cold.

If a large number of arterioles are constricted simultaneously while the heart continues to deliver the same amount of blood, the pressure in the main arteries will be increased because of the greater resistance offered to the flow of blood. As a result, the flow of blood will be increased in those areas where no constriction has taken place. It is in this manner that the blood supply to the brain is mainly regulated. The brain is inclosed in an inelastic shell of bone; the amount of blood within the skull cannot be much increased. When the pressure is raised, however, the velocity of the blood flow through the brain is accelerated so that a greater amount of blood passes through it in a given time. If the brain requires more blood, the remainder of the body has to do with less in order that the pressure may be increased by the constriction of the vessels. During mental concentration the blood pressure is raised; the extremities may feel chilly in consequence of their decreased circulation. The arteries in the brain are supplied with nerves, but constriction or dilatation of these arteries is probably more important in regulating the distribution of blood to the different parts of the brain than in regulating the total flow.

Besides the control of the arterioles exerted through nerves there is also a chemical regulation of their activity. The adrenal glands located close to the kidneys secrete chemical substances called adrenalin and cortin. Adrenalin constricts the arteries. It does not act through the nervous system; but the effects of its action, not only upon the blood vessels but also upon the bronchial tubes, the heart and intestines, are

similar to those caused by stimulation from the sympathetic nervous system.

Adrenalin, prepared as a medicinal substance, is sometimes applied directly to the blood vessels in minor surgery for the control of hemorrhage. Injected into the blood it affects the arteries in all parts of the body; as a result of the general constriction, the blood pressure rises. This internal secretion and also cortin are normally present in the blood in small amounts and may assist in maintaining the arterioles in a state of muscular tenseness or tonus. When the adrenal glands are removed or become diseased the blood pressure falls. The rise in blood pressure which accompanies excitement is, in part at least, occasioned by an increase in the secretion of the adrenal glands.

In the condition called Reynaud's disease the arteries, especially of the fingers and toes, constrict abnormally at times. The spasm of the vessels usually follows exposure to cold; the fingers or toes then feel numb and appear blue; when the spasm relaxes they become red, warm and painful. The cause of the disease is not known, but relief can often be obtained by cutting the sympathetic nerves which supply the arteries and so, in part at least, preventing the constriction.

Amount of Blood Pumped by the Heart.

The amount of blood pumped by the heart is an important factor in maintaining the pressure of the blood. A widespread dilation of the vessels may be compensated or more than compensated by an increased output of blood. Thus during muscular exercise the blood pressure rises, although the flow of blood to the exercising parts is increased. The amount of blood pumped by the heart varies with the general need of the body for oxygen. It varies also more or less in agreement with the rate of the heart. Thus in exercise the rate and the volume are both increased. This correspondence does not, however, always hold true. When the rate of the pulse is increased from emotion or as a result of drinking coffee or smoking, the flow of blood is not correspondingly increased; the stroke or output at each beat is therefore smaller. A similar condition occurs in fatigue.

The position of the body influences the amount of blood pumped by the heart. In most persons the flow of blood is 15 to 25 per cent greater while sitting than while standing, and an additional 15 to 25 per cent greater while lying down. The decrease in the amount of blood pumped in the standing position accounts in part for the fainting which occurs in men standing rigidly, as do soldiers at attention.

When a man of average size is sitting at rest his heart pumps from the left side from 4 to 7 liters of blood each minute, and an equal amount, of course, from the right side through the lungs to the left heart, making a total of 8 to 14 liters. Under severe exercise the volume pumped per minute may be tripled.

Measurement of Arterial Pressure.

The pressure of the blood as it is forced from the heart into the aorta is precisely that necessary to overcome the resistance offered to the flow of blood by the arteries, capillaries and veins. The energy imparted by the heart is dissipated in overcoming the resistance, therefore the pressure falls progressively as the blood flows through the smaller vessels. The term blood pressure, or more correctly arterial pressure, is taken to signify the pressure of blood on leaving the heart, hence essentially that of the large arteries such as the aorta or the brachial artery of the arm.

The arterial pressure rises and falls with each beat of the heart. The maximum or systolic pressure is reached during the contraction of the heart, and the minimum or diastolic during the relaxation. The difference between these two, the fluctuation with each heart beat, is known as the pulse pressure. Unless otherwise stated, the term "blood pressure" or arterial pressure signifies the systolic pressure. In many ways the diastolic pressure is more important, for it is the pressure to which the arteries are exposed at all times; it is the minimum load which the heart must carry in order to maintain the circulation.

The pressure of the blood in the large arteries is easily measured. To do so a cuff consisting of a flat rubber bag, loosely covered with cloth, is bound around the upper arm. The cuff is inflated with a bulb; as the pressure rises in the cuff it compresses the arm with increasing force. When the pressure of air in the cuff equals or slightly exceeds that of the blood, the artery is squeezed shut and the flow of blood stopped. A pressure gauge or mercury manometer indicates the air pressure within the cuff. The observer notes with his finger the pulse in the wrist of the subject. When the flow of blood stops the pulse is no longer felt. The pressure reading at this point indicates the approximate systolic arterial pressure. A more precise method of noting the cessation of blood flow is to listen to the sounds within the artery by means of a stethoscope placed at the inner surface of the elbow. No sound is heard from the uninterrupted flow of blood; likewise none when the pressure in the cuff exceeds the systolic pressure in the artery

and no blood flows. Between these two extremes a sound is heard with each heart beat as the walls of the artery are opened by the rising pressure of the blood and shut again by the cuff as the pressure falls. As the pressure in the cuff is gradually raised, a point is reached at which the sounds cease; the reading on the gauge at this point is taken as the systolic pressure. As the pressure in the cuff is then slowly released the sounds reappear and with changing quality until abruptly

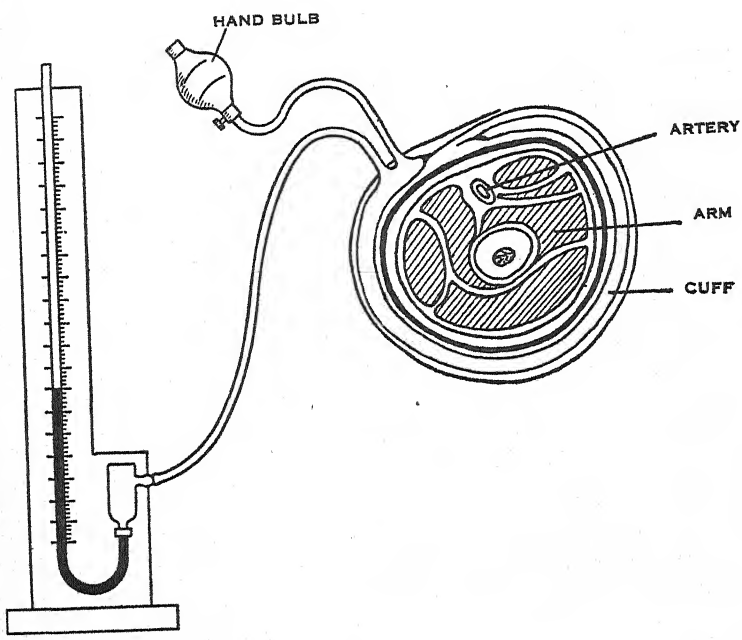


Figure 15. Measurement of Arterial Pressure.

they become muffled; slightly lower, they cease. The reading on the gauge at the muffled phase is taken as the diastolic pressure.

The gauge used in determining arterial pressure is always of a type comparable to a barometer. Like a barometer it reads in millimeters of mercury. It actually records the pressure of blood above the prevailing barometric pressure. Thus at sea level with a barometric reading of 760 mm. an arterial pressure recorded as 120 mm. systolic would signify a real or absolute pressure of 880 mm. (760 mm. + 120 mm.). This point is brought forward here because there is a general but erroneous

belief that at high altitudes the lower atmospheric pressure exerts less force to prevent the arteries from rupturing so that hemorrhage may result. The arterial pressures recorded at sea level and on the top of Pike's Peak (14,000 feet) are the same for any one individual. The respective barometric pressures are 760 and 450 mm. Thus a systolic blood pressure of 120 mm. in each locality signifies quite different absolute pressures—in one case 880 mm. and in the other 570 mm. In short, the absolute blood pressure falls with the barometer. Hemorrhages that may occur from the nose or mouth at high altitudes are not due to the lack of pressure on the outside of the arteries; they are due to the chapping and cracking of mucous membranes from excessive evaporation of fluid in the rarefied air.

Variations in Arterial Pressure.

Arterial pressure is observed with the subject in a state of rest and as free from emotion as possible. Excitement, even the excitement of having the arterial pressure measured, causes the pressure to rise. Because of this nervous influence the lowest pressure found in a number of trials is taken as the individual's average pressure. Arterial pressure varies with age. At birth the systolic pressure is about 50 mm.; at five to seven years it may reach 100 mm.; at fifteen years, perhaps 115 to 120. There can be no question that these changes with age are normal; whether further rise with age is normal or abnormal and at exactly what point the pressure becomes abnormally high are questions that are not settled. Arterial pressure has no set normal as does the body temperature; instead, it shows wide individual variations. Values obtained from observations made on large numbers of individuals between the ages of sixteen and forty give an average of about 115 mm. for women and 125 mm. for men. But among these individuals there would be some with pressures as low as 85 mm. and others with pressures as high as 175; there would also be all gradations between these extremes. The majority, however, would fall in a range extending from 10 mm. below to 10 mm. above the averages given. It has often been stated that for an adult the normal arterial pressure in mm. should be 100 plus the age in years, i.e., 120 at twenty years, 140 at forty, and 170 at seventy. Such values are commonly found. Nevertheless, at any age a pressure consistently above 150 or 155 mm. during rest and freedom from emotional excitement may be safely said to be abnormally high. The tendency in medicine is to lower rather than raise the figure which is taken as the dividing point. Although women

between the ages of sixteen and forty have, on the average, a somewhat lower arterial pressure than men, these relations are altered after fifty; the average pressure for women rises then and becomes higher than that for men.

In a general way the diastolic pressure follows the systolic, running from 30 to 50 mm. below it. The diastolic pressure rises when the resistance to the flow of blood in the arterioles is increased. If the heart is healthy this increase is compensated by more forceful contractions of the heart so that the pulse pressure is not greatly changed. If the heart is not capable of carrying the added load, signs of cardiac fatigue or failure appear, and the size of stroke and with it the pulse pressure are decreased.

Many conditions cause a brief variation in the arterial pressure. Emotion, mental concentration and worry are accompanied by a rise in the pressure. A rise of 50 per cent has been observed in a professor while delivering a difficult lecture; and if it is a good lecture and closely followed, it may cause half as great a rise in his auditors. The effect of muscular exercise is variable. Moderate exertion, such as walking, may cause the diastolic pressure to diminish without markedly influencing the systolic, thus increasing the pulse pressure. Severe exertion, on the contrary, tends to increase both the diastolic and systolic. Tobacco and coffee usually cause a rise of arterial pressure, while hot baths, or high temperature from any cause, tend to diminish it. Severe exercise performed under warm surroundings, however, results in arterial pressure higher than a similar exertion performed under cool surroundings.

On lying down, the arterial pressure normally drops from 10 to 20 mm.; a rise by a similar amount follows the return to the erect position. The variation in pressure accompanying change in position is due to an alteration in the size of the arterioles, especially in the abdomen. The heightened pressure in the erect position tends to compensate for the increased hydrostatic pressure against which the blood to the brain must be pumped. The response of arterial pressure to change in position varies in different people and in some may even be the reverse of the usual; it is not always constant in the same person. To some extent the pressure change is an expression of the state of the nervous system. The momentary period of dizziness, headache or blindness which many persons experience in rising suddenly from the recumbent position, is caused by a diminished flow of blood through the brain resulting from a lag in the compensatory reaction of the blood pressure.

The adjustment of arterial pressure to position is largely under the control of a nervous reflex. The stimulation for the reflex is derived from pressure changes within a slight dilatation of the carotid artery in the neck at a point on a line with the angle of the jaw. This dilatation is known as the carotid sinus; the nerves which surround it extend to the centers in the brain which control the rate of the heart and the size of the blood vessels. When the pressure in the sinus falls, heart rate is increased, the blood vessels throughout the body are constricted, and the arterial pressure rises. If the sinus is pressed upon from the outside by the fingers, the heart is usually slowed and the arterial pressure decreased. Some individuals are highly sensitive in their response to pressure upon the carotid sinus; shaving the skin of the neck or buttoning a tight collar may result in dizziness, even fainting.

Chronically Low Blood Pressure—Hypotension.

For adults an arterial pressure of 110 mm. is taken as the lower limit of the normal range. Decision upon this particular figure is wholly arbitrary, and although it is said that individuals with pressures below this value suffer from hypotension, the fact remains that many have no ill effects whatever but lead long and vigorous lives. There are others, however, in whom the low pressure is associated with definite symptoms; they lack energy, tire easily, are subject to dizzy spells and headaches, and have periods of depression; often their hands and feet are cold. Such individuals are mainly tall, thin, and poorly developed physically. It is impossible to determine whether these symptoms arise from the low pressure itself or from the more fundamental disturbance which causes the hypotension. Usually no definite cause can be found for the low pressure, although occasionally it is an accompaniment of tuberculosis and other chronic diseases. Disease of the adrenal glands with insufficient secretion of a substance known as cortin results, along with other symptoms, in very low arterial pressure. This rare disturbance is known as Addison's disease; formerly almost invariably fatal, it can now be treated successfully with an extract made from the outer part or cortex of the adrenal gland.

Chronic High Arterial Pressure—Hypertension.

Chronic high arterial pressure is a far more common disturbance than low arterial pressure. The condition itself sometimes gives rise to symptoms such as dizziness, headache, insomnia, and irritability, but its great importance lies in the fact that it burdens the heart and injures

the arteries. Hypertension is one of the prime causes of hardened arteries, arteriosclerosis.

The dividing line between normal and abnormal pressure is usually placed at 150 or 155 mm. for the systolic and 95 mm. for the diastolic. In most cases of permanently high blood pressure the cause cannot be discovered; the condition is then spoken of as essential hypertension. Many possible causes have been suggested: diet, overweight, focal infections, age, excessive use of table salt or tobacco, and the stress and strain of modern life. While any one of these factors might conceivably influence the course of hypertension, there is no evidence that any one is directly responsible for the condition. Chronic high arterial pressure is found in association with no particular diet; it may occur in those who are thin as well as in those who are fat, in those who use little table salt as well as those who use excessive amounts, and in non-smokers as well as in smokers. It is much more prevalent in old people than in young, but some aged individuals may have low pressure; hypertension sometimes develops in the teens and even earlier. Probably the most important factor is heredity; the condition is prone to affect many members of a family through successive generations.

It is not known with certainty how heredity or any other factor operates to bring about essential hypertension. The presumption is that the smaller arteries contract abnormally, thus increasing resistance to the flow of blood. The arterial pressure rises to overcome this resistance. But the cause of the abnormal constriction remains unknown. It may be brought about through the action of the sympathetic nervous system which normally controls the constriction of the arteries. Surgical operations in which the nerves to the blood vessels in the chest and abdomen are cut have, in some cases, resulted in a relaxation of the arteries with a fall of arterial pressure. But this fact offers no explanation for hypertension. The basic disturbance may be in the nervous system, in the glands of internal secretion, in the response of the vessels themselves, or it may be elsewhere.

One type of chronic high arterial pressure called renal hypertension is associated with kidney disease. It has been shown experimentally that when the flow of blood through the kidneys is partially but not completely obstructed, arterial pressure rises. The rise in arterial pressure may be the first indication of the occurrence of disease in the kidneys; in turn, high arterial pressure from any cause may be followed by disease changes in the kidneys.

In occasional instances persistently high arterial pressure may result

from emotional disturbance as a psychoneurotic manifestation. Usually the individuals so affected are of abnormally anxious temperament; the rise in pressure is commonly the outcome of some persistent and difficult social situation which entails a burden of responsibility. Solution of the social situation with relief of responsibility may be followed by a fall in the arterial pressure. A similar amenability to treatment by any known method is rarely exhibited by the far more common type of essential hypertension.

Chronic high arterial pressure increases the work of the heart. The energy expended by the heart in pumping a given quantity of blood is proportional to the pressure against which it must pump it. The increased pressure is much more marked in the systemic circulation than in that through the lungs. Therefore it is the left side of the heart which bears the added burden. The heart muscle may be stretched by the high pressure so that the left ventricle becomes larger, dilated; the muscle, because of the greater work it is forced to perform, also grows thicker. Chronic high arterial pressure, therefore, leads in time to an enlargement of the left side of the heart. A heart that is dilated is not as strong and resistant as a heart of normal size.

Arteriosclerosis.

Hardening of the arteries is frequently associated with high arterial pressure. But the relation is not reciprocal. In time high arterial pressure leads to arteriosclerosis; but arteriosclerosis, resulting as it may from other causes, does not lead to high arterial pressure.

The term arteriosclerosis as generally employed embraces all changes in an artery, *not caused by inflammation as from infection,* that affect the smoothness, thickness, uniformity, and elasticity of the tissue of the artery. From this classification there is sometimes excluded those changes which are believed to result wholly from age. Usually between forty and fifty the arteries, like other tissues of the body, begin to show signs of aging; they become dryer and tougher and lose some of their elasticity; they also become longer and hence tend to follow tortuous courses, as can often be seen in the arteries on the temples.

Age alone, presumably, does not produce other changes seen in arteriosclerosis; they are believed to be the result of disease. There are two broad types of these changes. One type, called the atheromatous, is a local degeneration. In spots large or small, the cells of the inner wall of the artery overgrow, producing a mass that eventually degenerates, leaving a ragged sore, or else becomes infiltrated with fat-like sub-

stances such as cholesterol or with calcium salts to form hardened and fragile placques in the wall of the artery. Atheromatous changes occur mainly in the larger arteries, especially the aorta. From such changes an artery, as of the arm, may, over a considerable distance, become as hard and nearly as stiff as a clay pipestem. The other general sort of arteriosclerosis occurs mainly in the small arteries; it is a true sclerosis in which the connective tissue in the outer walls of the artery increases in amount, stiffening and hardening the artery. The changes in an artery as the result of sclerosis have been likened to those occurring in a rubber tube exposed for a long time to light and air; the normal elasticity is lost, cracks appear and the tube becomes stiff and fragile.

Arteriosclerosis is an almost inevitable accompaniment of age; most men over forty show the disease in some degree. Some individuals, however, develop marked arteriosclerosis at forty while others show little at eighty. Arteriosclerosis is sometimes held to be a part of the physiological process of aging; it is more probable that age operates here to allow a longer time for the action of any factor causing arteriosclerosis.

The problem of the cause of arteriosclerosis is the most important of modern medicine, for arteriosclerosis, directly or indirectly, is the greatest single cause of death. Arteriosclerosis probably represents the response of the arteries to the sum total of the wear and injuries to which they are subjected. The resistance with which the arteries withstand injury before becoming sclerotic is determined by the quality of tissue in the vessel walls. This quality is in turn determined by the individual's hereditary endowment. Longevity, barring accidents, is largely a matter of heredity, and longevity depends upon how long the arteries can withstand the forces that injure them. This idea is expressed in the axiom that "a man is as old as his arteries."

No doubt many different forces conspire to cause arteriosclerosis; the more important ones that have been implicated are listed and discussed here.

Infection.

Arteriosclerosis is not an infection, but infections may injure the arteries just as they do other parts of the body. Thus in rare instances arteriosclerosis has developed with such rapidity following pneumonia, typhoid fever, and other diseases as to leave no doubt as to the causal relation in these particular and unusual instances. The fact that acute infections may lead to arteriosclerosis has suggested the possibility that

chronic infections, as from teeth and tonsils, may contribute toward the development of the disease. There is no definite proof to confirm this belief.

Poisons.

It is improbable that the cause of arteriosclerosis is to be found in any toxic substance inhaled, ingested, or otherwise brought into the body. To this statement there is one exception. Chronic exposure to lead as an occupational hazard may be followed by early arteriosclerosis. Tobacco has been implicated as a cause, but not definitely established. In some individuals smoking causes a constriction of the arteries near the skin; it does not in others. Arteriosclerosis occurs in non-smokers as well as in smokers, but tobacco remains under suspicion. Alcohol, once held as a potent cause, is now largely exonerated.

The Stress and Strain of Modern Life.

There is no certain evidence that the speed, stress, strain, or competitive spirit of modern life contributes appreciably to the onset of arteriosclerosis. Arteriosclerosis was common in ancient Egypt, as is shown from the examination of mummies; it affects animals other than man, especially those living the calmer life of domestication—particularly the cow and the duck, neither of which has a strenuous life.

Diet.

Many articles of diet, but especially protein and table salt, have been considered causes of arteriosclerosis. There is no valid reason to believe that either meat or table salt hurts the arteries except indirectly in the presence of existing kidney disease. It has been shown that when rabbits (which cannot tolerate a meat diet) are fed cholesterol, atheromatous patches develop in the aorta. The theory has been advanced that arteriosclerosis may result as a sort of gout in which the body fails properly to utilize and eliminate cholesterol, with the result that it is deposited in the walls of the arteries, much as uric acid is deposited in the joints. No valid evidence, however, has been obtained to show that cholesterol in the diet of the human being in any way contributes to arteriosclerosis.

Hypertension.

The connection between hypertension and arteriosclerosis is certain. The high pressure is one of the forces known to injure the arteries

directly. This knowledge, however, affords little assistance toward avoiding arteriosclerosis. In most instances the cause of hypertension is not known.

Infection of Arteries.

Sclerosis is not the only disease of the arteries; they are especially susceptible to damage during infection with syphilis. The treponema which causes this disease attacks the arteries, causing a slowly developing overgrowth and weakening of the walls of the arteries, especially the aorta. The damage is irreparable although it can be entirely prevented by early treatment of the syphilitic infection. The consequences of syphilitic arterial disease are essentially the same as those from arteriosclerosis but usually appear earlier in life.

Still another disease of the arteries is known as thrombo-angiitis obliterans, or Buerger's disease. It affects mainly the vessels in the legs. It starts with an inflammation of the arteries (angiitis); next the walls become roughened and clots form (the thrombo of the technical name); and finally, scars formed in the artery partially obliterate the vessel. The consequences of the restricted flow of blood are essentially the same as those that may result from arteriosclerosis to be discussed in the next section.

Buerger's disease has many of the characteristics of an infection, but the cause has not been discovered. The disease exhibits as yet unexplained peculiarities in its occurrence; it affects Jews mainly and males almost exclusively, but only those who are heavy tobacco smokers.

Consequences of Arteriosclerosis.

Arteriosclerosis may sometimes be borne for many years without noticeable effect. Often it is not detected until some serious consequence has occurred. If a large artery near the surface is hardened the stiffness of the walls may sometimes be felt; a deeper artery infiltrated with calcium may show on X-ray examination. The retina of the eye offers the only opportunity of looking directly upon exposed arteries; the vessels there may be seen when the interior of the eye is illuminated with an ophthalmoscope. Hardening of an artery in one part of the body does not invariably indicate hardening in any other part, but the condition of the arteries in the two most crucial regions, the heart and the brain, is believed to correspond closely with that of the vessels in the retina.

The serious consequences of arteriosclerosis arise in three ways: (1)

the constriction of the artery may restrict the flow of blood to some part of the body; (2) the weakened or brittle blood vessel may break under the strain of the pressure of the blood within it; and (3) the roughening of the walls predisposes to the formation of clots within the artery, thrombosis.

The symptoms which accompany partial obstruction to the flow of blood depend upon the organ affected. If it occurs in the vessels of the heart, the coronary arteries, serious damage is done to this organ; its results may show as chronic myocarditis or angina pectoris, both of which are discussed in the following chapter under diseases of the heart. In the brain a restricted flow may occasion loss of memory and dulled wits, and other mental changes often seen in old age. In the legs the muscles are partially starved by the restricted flow; pain, fatigue, and often limping follow slight exertion. The starved tissues lose some of their reparative ability and resistance to infection. Linaments, antiseptics and ointments, harmless when applied to normal skin, may cause persistent ulcers in the undernourished flesh. Small injuries, as from a scratch by an improperly trimmed toe nail, may be followed by serious infections.

Rupture of a hardened vessel occurs most commonly in the retina of the eye, causing partial blindness, and in the brain, leading to cerebral hemorrhage, one form of apoplexy. Hemorrhage into the brain is followed by unconsciousness and paralysis; if it is large, by death.

Thrombosis of the sclerosed vessel may occur in any part of the body, but its consequences are most serious in the brain and heart. Cerebral thrombosis or embolism results in a form of apoplexy, generally less fatal than cerebral hemorrhage but often resulting in paralysis. In the heart the thrombosis occludes the coronary arteries; the attack usually causes intense pain and is often fatal (see page 179).

Aneurism.

When an artery becomes weakened through disease, or is subjected to unusual strain, it may bulge out over part of its length, or give way in one spot and form a sac filled with blood. The enlarged portion is known as an aneurism. The aorta is the artery most commonly affected; next in order is the femoral artery at the point in the leg where it passes behind the knee joint.

The strain of sudden violent muscular exertion may cause an artery to give way and form an aneurism. Aneurism may also occur in a vessel which has become injured from a wound or a severe blow. In-

fectious diseases such as typhoid may damage the arteries and lead to the formation of aneurisms; similarly areas in the walls of hardened arteries may give way. The greatest cause of aneurism, particularly that of the aorta, is syphilis. This is especially the case when the infection is associated with a high blood pressure. An aneurism of the aorta may become so large that its pressure erodes the breastbone; a pulsating mass then appears beneath the skin of the chest. The particular dangers from aneurism lie in the possibility that the weakened walls of the artery may rupture, causing a serious or even fatal hemorrhage, or that thrombosis occurring in the stagnant blood will cause embolism.

Varicose Veins.

A vein is said to be varicosed when it has become dilated and lengthened. Because of its lengthening the vein follows a tortuous course. The veins most commonly affected are those of the legs, those that follow the spermatic cord into the scrotum, and those in the rectum and about the anus. The irregular enlargement which can be felt in the scrotum when the veins there are varicosed is known as a varicocele. Varicosed veins about the rectum are known as hemorrhoids or piles.

The superficial veins of the leg normally have many check valves which divide them into segments. The valves permit a flow of blood only in the direction of the heart. Some of these segments are connected by branches to other veins placed deep in the muscles of the leg. The valves of the communicating veins permit the blood to flow from the superficial to the deep veins. In the groin the two systems unite in a common trunk which joins the venae cavae in the abdomen. Every movement of the leg muscles compresses the veins and passes the blood from one segment to the next, while the valves prevent return. When one stands without moving the legs, the blood collects in the veins until a hydrostatic pressure accumulates sufficient to lift the blood to the heart. Anyone who stands still for a long time experiences the discomfort and swelling of the legs which arises when the flow of blood is not assisted by the movement of the muscles. The loss of the valves in the veins of the legs results in the veins becoming varicosed. This destruction of the valves is usually brought about by the increased abdominal pressure which results from strain as in lifting heavy objects. The blood in veins within the abdomen is forced back against the valves in those of the legs. The deep veins are reinforced by the muscles about them, but the superficial veins which have no such pro-

tection are stretched under the increased pressure and their valves are destroyed.

In the absence of valves the action of the muscles can no longer assist the flow of blood, so that whenever the body is erect, whether the legs are stationary or not, the superficial veins carry a high pressure. Furthermore, the deep and superficial veins are connected both along their course and at the top. The pumping action within the deep veins which have maintained their valves draws in the blood from the varicosed veins through the lower communicating channels. At the same time the varicosed veins are kept filled with blood through the junction of the two sets in the groin. A reversal of the blood flow in the outer veins is thus produced, and the blood is recirculated in the leg; congestion follows. Varicosed veins of the leg are readily distinguished from normal veins. The blood can flow down them as well as up. Therefore when the leg is first elevated and then lowered, the veins are immediately filled. In a normal vein, on the contrary, as much time as half a minute is required to fill the leg veins.

Varicose veins of the leg occur most commonly in men who do hard physical work, or whose occupations cause them to stand many hours each day, and more particularly under both conditions. Among women the cause is almost always childbearing. The pressure from tight garters may be a contributing factor.

The disabling complication of varicosed veins is the formation of ulcers. In the leg the poor circulation from varicosed veins retards the normal healing process so that slight scratches or bruises lead to open sores which may persist for many years. In extreme cases, among persons with uncleanly habits, flies may lay their eggs in the unhealthy flesh which becomes riddled with maggots. Another complication of varicosed veins is thrombosis, sometimes with inflammation, phlebitis. The stagnation of the blood flow is the predisposing factor to the formation of the clot. Varicosed veins of the leg are treated either by surgical removal or through the wearing of supporting stockings or bandages.

Hemorrhoids.

The veins of the rectum have no valves and varicosity in them is caused by simple dilatation. Like the superficial veins of the leg, they are held in a loose tissue so that they lack support. If the pressure of the blood within them is markedly increased they may be stretched. The pressure of the blood in a vein is low only so long as the flow is

unobstructed. When the vein is blocked the pressure in it gradually rises until it equals that in the artery which supplies it. The act of defecation, particularly if it is difficult or prolonged, increases the pressure within the veins of the rectum. Chronic constipation is, therefore, a predisposing factor to hemorrhoids. Hemorrhoids are common in young persons, especially men of about twenty years who lead sedentary lives. Young women are usually quite free from the condition, although it may occur after pregnancy.

Hemorrhoids are often present without the individual being aware of it. The condition, popularly called an "attack of piles," may be brought into prominence through the occurrence of thrombosis in the vessels. The thrombosis is frequently brought on by the use of violent purgatives or by local exposure to damp or cold, as by sitting on a cold wet stone.

Piles are spoken of as external and internal. The external variety project through the anus as dark brown folds of skin. They usually give rise to no discomfort beyond some itching and perhaps slight irritation immediately before and after defecation. When thrombosis occurs within them they appear as swellings of bluish color which are painful and tender, often preventing the sufferer from sitting or walking in comfort. If further irritation is prevented the inflammation usually subsides after a few days, or it can be relieved by removing the blood clot by surgical operation. Internal piles are covered with the mucous membrane which lines the rectum. At first they are held above the anus. Later, however, they tend to protrude. This type of hemorrhoid is very prone to bleed. The persistent hemorrhage may lead to anemia. Internal piles usually cause much more discomfort than the external type but are less liable to inflammation. Internal piles may be benefited by relieving constipation and improving the general health. If pain and bleeding persist, the dilated veins may be removed by surgical operation.

Birthmarks.

Although moles (see Chapter XII) belong in the category of birthmarks, the term is usually limited to blemishes resulting from abnormalities in the blood vessels near the skin. The commonest type consists of a mass of arterioles; it is small, rarely over an inch or two in diameter, is raised slightly above the surrounding skin, and appears red. The "port wine" stain, a less common form, consists of a fine network of capillaries and venules; the deoxygenated blood imparts a purplish

color. This type of birthmark does not project above the skin but frequently covers a large area involving at times one-half the face. Birthmarks develop before or soon after the child is born. Contrary to an ancient superstition, their formation has nothing whatever to do with the mental state, health of the mother, or any accidents prior to or during the birth of the child (see Chapter XX). It is often possible to remedy this condition in infancy by measures which obliterate the abnormal vessels.

CHAPTER VII

THE HEART AND ITS DISORDERS; THE LYMPHATIC SYSTEM

Position of the Heart.

When the chest is opened by removing the ribs, the heart is seen as a somewhat conical-shaped organ with the base uppermost and to the right, and with the apex projecting down and to the left. In consequence of its oblique position, about two-thirds of the heart lies to the left and one-third to the right of the mid-line of the body. The normal heart of an adult of average size is 12.5 to 15 centimeters (5 to 6 inches) in length, and 7.5 to 10 centimeters (3 to 4 inches) in breadth at the base; it weighs from 250 to 450 grams (9 to 15 ounces), with an average of about 300 grams (11 ounces). In disease the heart may grow to much greater size and weight. The normal heart in systole is about the size and the general shape of the left fist held over the chest.

The heart has no attachments except at the top, where the great vessels emerge. The apex of the heart moves from side to side with change in position of the body. In lying on the left side the heart can often be felt as it strikes against the inner wall of the chest. The common belief that sleeping on the left side harms the heart is a fallacy.

Pericardium.

The heart is enclosed in a double-walled sac of thin tissue called the pericardium, meaning "about the heart." Pericardium is similar in structure and appearance to the peritoneum which covers the intestines and abdominal cavity. The pericardial sac fills most of the space between the two lungs and is attached below to the diaphragm. The closed top of the sac turns in to surround the heart; the arrangement is much the same as if the clenched fist, representing the heart, were pushing in the top of a closed bag. The part of the pericardium which is thus turned in is attached to the heart. The outer layer is loose and the space between the two layers has in it a very small quantity of fluid. During the movements of the heart the smooth inner surfaces of the two layers of the pericardium rub together. Inflammation of the peri-

cardial sac as a result of infection is called pericarditis; the sac may then become filled with fluid or pus and the movements of the heart be impeded. (See Figure 32.)

Structure of the Heart.

As pointed out in the previous chapter, the heart is a pump. In structure it is a muscular bulb divided by a partition into two auricles

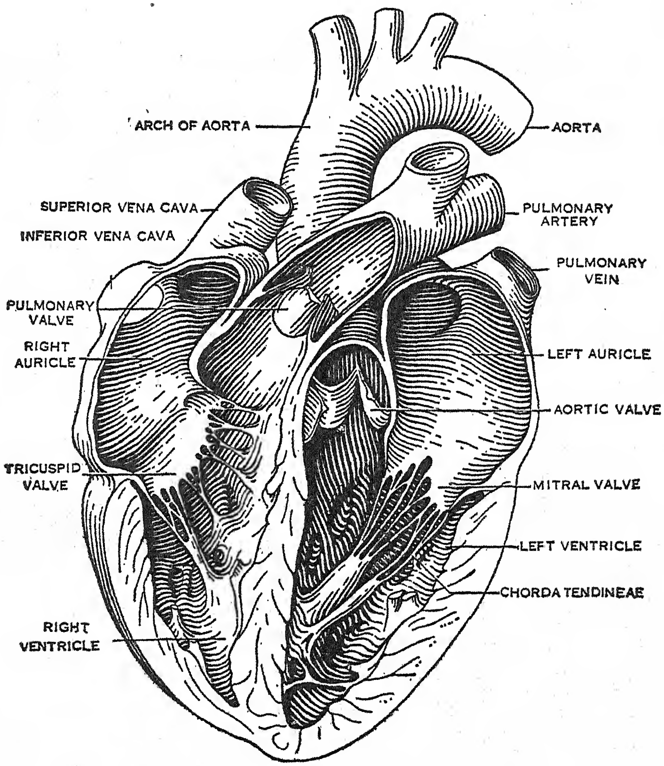


Figure 16. Longitudinal Section of Heart.

and two ventricles. It is thus not one, but two, pumps. The walls of the auricles are thin, for these chambers, together with the veins which supply them, serve largely as passive reservoirs in which blood accumulates during the contraction of the ventricles, and from which the blood empties into the ventricles during their relaxation. There are no valves separating the auricles from the veins. The muscular walls

of the ventricles are thick, for it is these chambers which force the blood under pressure into the arteries.

Between the auricles and their corresponding ventricles there are check valves which allow the blood to flow into the ventricle but prevent its return. The valve separating the right auricle and ventricle is called the tricuspid; that separating the left auricle and ventricle, the mitral valve. The orifice for each valve is formed by a strong fibrous ring connected on its periphery to the walls of the heart. Each valve is formed by a sleeve of thin, flexible, but very strong tissue attached to

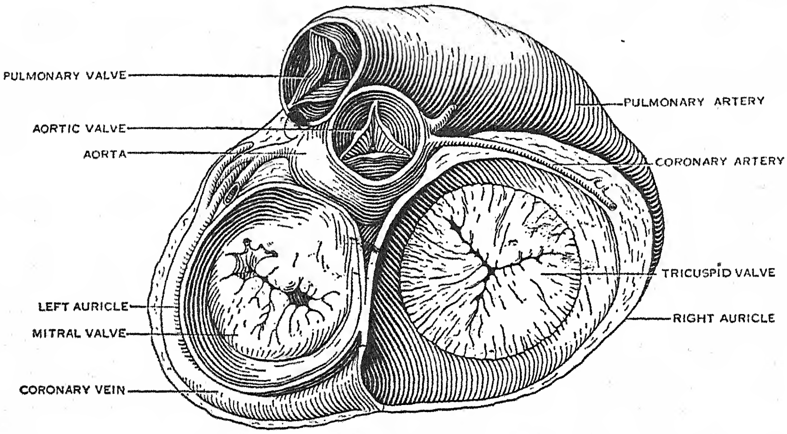


Figure 17. Cross Section of Heart.
Section made through the auricles.

the sides of the orifice. When the valve is open this sleeve extends into the ventricle. The sleeve of the mitral valve is split longitudinally in two places, and that of the tricuspid in three. Strong fibers or cords attach the under surface of the valve to the walls of the ventricle, serving as checks to prevent the valves from being forced back into the auricles under the pressure of the blood in the contracting ventricles.

The valves which close the opening between the ventricles and the arteries into which they inject their blood are called semilunar. They are also named for the corresponding arteries, the pulmonic and the aortic. Each of these valves is formed of three triangular, or semilunar, folds of tissue. The base of each fold is attached to the ring of connective tissue at the orifice of the valve. The apex of each triangular fold has a small bead or thickening at the point where the three folds meet when closed.

The muscle of the heart shows under the microscope some difference in structure from that of the skeletal or voluntary muscles, as in the biceps, and also from that of the involuntary muscles, as in the intestines. The heart muscle is known technically as myocardium; when it is diseased, the condition is called myocarditis. The chambers of the heart are lined with endothelial tissue continuous with that lining the blood vessels. In the heart this layer is known as endocardium; inflammation of the endocardium is called endocarditis.

Heart Sounds.

When the ear is placed against the chest wall over the heart, definite sounds are heard. They are produced by the activity of the heart. There is first a dull, long-drawn-out sound which is immediately followed by a second, which is short and sharp. A pause then occurs, after which the cycle of sound is repeated. The normal heart sounds resemble the words "l-u-b dub," pause, "l-u-b dub," pause, and so on.

Great importance is attached to the heart sounds in the diagnosis of disease. The physician listens to the heart usually with a stethoscope. This instrument does not amplify the heart sounds, but allows the physician to use both ears and permits a smaller area to be examined than is otherwise possible. The sequence of cardiac events associated with the normal heart sounds are as follows: During the pause in the heart sounds the ventricles relax; the muscle becomes soft, flabby and distensible, and the pressure within low. The blood from the veins that has accumulated in the auricles pours down into the ventricles through valves—mitral in the left heart, tricuspid in the right. The ventricles fill; the downward flow of blood stops and the valves close; no blood can flow back from the ventricles into the auricles. Contraction then starts: the muscle of the ventricles squeezes down on the blood in its chambers; the vibration of the tensed muscle gives rise to the "l-u-b" heart sound. The pressure of the blood in the ventricles rises until it equals, and then exceeds, that in the arteries; it pushes open the valves to the aorta (the aortic valve) and to the pulmonary artery (pulmonic valve) and is squirted into the arteries. The ventricles having discharged their contents start to relax, the pressure within falls, the higher pressure in the arteries forces shut the aortic and pulmonic valves, and no blood can then flow back from the arteries to the ventricles. The snapping shut of these valves gives the "dub" sound that follows immediately after the "l-u-b." There is a pause in sounds as the ventricle fills again and the cycle starts over.

Abnormal sounds arising from the heart, called murmurs, often result from disease of the heart valves. By determining the time relation between the murmur and the normal heart sound deductions can be made as to which of the valves is affected. Each valve may have two general defects; it may leak (technically, insufficiency or regurgitation), or it may be constricted in size so that the flow of blood is impeded (technically, stenosis). In mitral insufficiency some blood will pass abnormally from the ventricle back into the auricle during systole. The back flow of blood will cause a murmur which will occur at the time of the normal "l-u-b" sound of the heart—a systolic murmur. In mitral stenosis the blood flowing through the scarred and constricted valve orifice causes a murmur but it will be heard during diastole. For the same two defects in the aortic valve the time relations of the murmurs will be the reverse of those in the mitral valve; insufficiency will cause a murmur during diastole, and stenosis during systole. The murmurs from the aortic valve will usually be heard loudest near the base of the heart; those from the mitral valve, near the apex.

The presence of murmurs does not always signify a diseased heart. These abnormal sounds may occur temporarily during anemia, fever, and other conditions in which the heart valves are unaffected. They may also occur and persist throughout life when nothing else abnormal can be found in the heart. Such murmurs, which are usually systolic in the time of their occurrence, are called functional murmurs to differentiate them from those caused by disease. A murmur becomes suggestive of disease when the individual showing it has had rheumatic fever; more so when the heart is enlarged.

Work Done by the Heart.

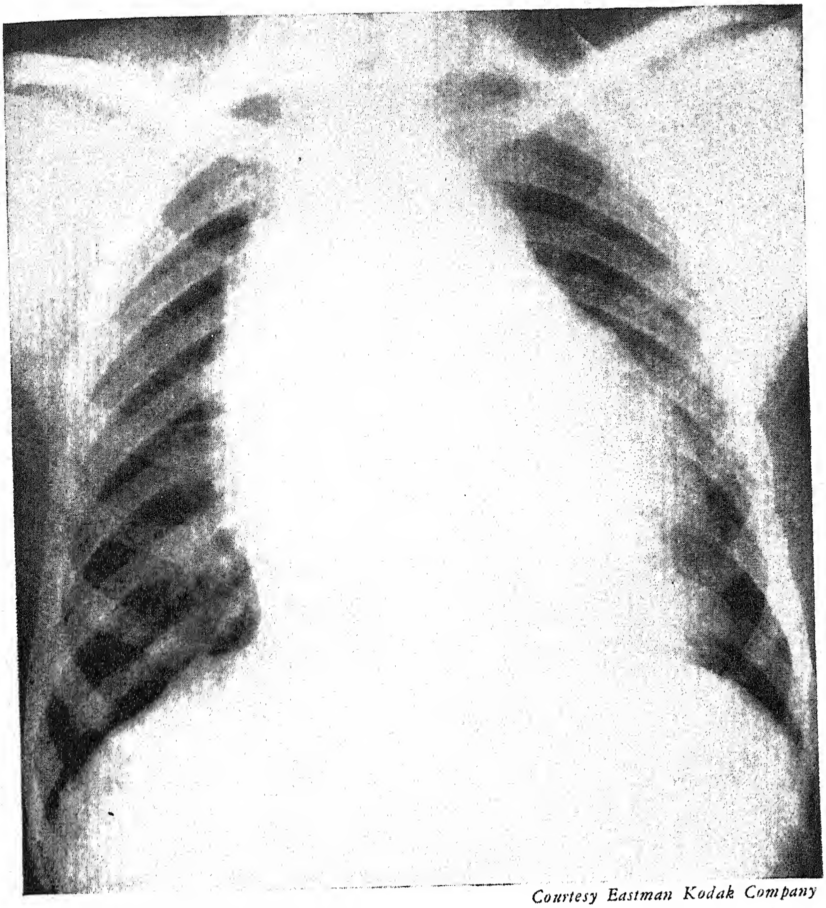
The work done by the heart in circulating the blood depends upon the volume of blood pumped in a given time and the pressure against which it must be forced. For a man at rest about 5 to 8 liters or kilos (approximately 10 to 16 pounds) of blood pass through the left ventricle each minute. As we have seen (Chapter VI), the pressure in the arteries is approximately that of a column of water six feet high —i.e., 128 millimeters of mercury. Therefore, in each minute 10 to 16 pounds of blood are raised 6 feet, and from 60 to 96 foot pounds of work are done. Sixty foot pounds a minute come to 3600 foot pounds an hour, or 86,500 foot pounds in twenty-four hours. The left heart of a man who is at rest thus does a minimum daily work equivalent to lifting the man through a vertical distance of over 500 feet.

With a uniform output of blood the work done by the heart varies in proportion to the pressure against which the blood must be pumped. Therefore, in chronic high arterial pressure the heart is forced to do more work to circulate the blood than when the pressure is normal. During exercise the volume of blood pumped may be three or more times as great as in the resting state, and the blood pressure may rise 50 per cent or more. The work of the heart may thus be increased fivefold.

Enlargement of the Heart.

The size of the heart can be roughly approximated by percussion, i.e., by tapping with the fingers over the chest wall and noting the quality of the sound elicited; the area of dullness thus defined is over the heart. The size as thus determined can be confirmed in part by measuring the distance from the center of the breastbone to the point where the apex of the heart beats against the chest wall. Far better estimates of the size of the heart can be obtained by X-ray examination.

The weight of the normal heart bears a rough relation to the weight of the body, but it follows more closely the development of muscle than the deposition of fat. Contrary to wide popular belief, the exertion of violent athletics increases the size of the heart to no greater extent than it develops the mass of the body's muscle; athletes do not have larger hearts than non-athletes of the same muscular build. And, to judge from mortality records of college graduates, athletics, again contrary to wide popular belief, do not contribute to heart disease in late life. The life expectancies of the non-athletic and athletic groups agree within two months in a lifetime of over sixty years. The former athletes, with the passage of years, develop the same heart and artery diseases as do the non-athletes—no more, no less. These facts, demonstrated in supervised athletics of well-trained young adults, cannot be applied to all athletics. In immaturity (as of the school boy) it is possible, and in convalescence after illness where there is lack of medical supervision in athletics, certain, that the heart may be damaged by unduly violent exertion. Likewise the heart of an individual, no matter how athletic he may have been in former years, loses strength with age and lack of constant physical training. Under these conditions his heart may be dilated and injured by attempts at exertions which in younger years were carried out with ease. For the middle-aged and untrained individual it is a wise policy to stop exertion before marked shortness of breath has developed.



Courtesy Eastman Kodak Company

PLATE III. Radiograph showing enlargement of the heart. See page 164. Compare the enormous shadow cast by this diseased heart with that for a normal heart shown in Plate IV. The broad white area below the heart is the shadow cast by the diaphragm.

What is known as dilatation of the heart results only from disease. The chambers of the heart are then abnormally increased in capacity. Dilatation may occur suddenly as the weakened walls yield to the pressure of the blood, but more often it develops slowly as the result of gradual stretching. The nature of the condition causing the dilatation determines which chambers of the heart will dilate. Thus in mitral stenosis the passage of the blood from the left auricle to the left ventricle is impeded; the auricle dilates from the pressure of the blood dammed back in it. In aortic insufficiency blood leaks back into the left ventricle and it is then this chamber which dilates. Dilatation of the left ventricle may also occur from chronic high arterial pressure.

Dilatation is not the only cause of enlargement of the heart; the heart muscle may grow heavier and the heart increase in weight as well as size. This hypertrophy of the muscle gives greater strength and allows the heart to perform more work in overcoming the handicaps imposed by leaking valves or high arterial pressure. The heart may thus partially compensate for these diseases. Enlargement of this sort is not, however, of exactly the same nature as the ordinary hypertrophy of a muscle, such as the biceps, in response to work; it is believed that in part, at least, the growth is stimulated by injury to the heart muscle. Hypertrophy is classed as an abnormality, a sign that the heart is affected by disease.

Cause of the Heartbeats.

The heart is to a large extent a self-contained mechanism. Even when it is removed from the body, if it is kept warm and supplied with a nutrient and oxygenated fluid, it continues to beat; it will pump the fluid. The power of rhythmic contraction by which it pumps blood is, therefore, intrinsic in the heart. The heart depends upon the remainder of the body only for food and warmth, and for the controlling influences which govern the rate of its beat.

The muscle of the heart has the properties common to all muscles; that is, it will contract when some external force stimulates it. Unlike most other muscles, however, that of the heart has the property of initiating contraction spontaneously and rhythmically; it is automatic. Even a piece of muscle separated from the heart will continue to beat, although it receives no stimulation from the outside. Within the heart muscle a cyclic process occurs; products of some nature accumulate until finally a point is reached when this internal stimulation induces a contraction. For a brief time, the so-called refractory period

lasting a fraction of a second after its contraction, the heart muscle is unable to contract again, even though it is stimulated from the outside. Its ability to respond soon returns. When one group of the minute fibers which make up the heart muscle contracts, it stimulates its neighbors and they in turn stimulate others, so that the entire organ contracts, nearly simultaneously. Thus a contraction which has been initiated in any region of the ventricle or auricle is conducted to adjoining regions and tends to produce a nearly simultaneous contraction of the whole ventricle or auricle.

Although any portion of the heart muscle is inherently capable of thus initiating contractions, the rate of the whole heart is ordinarily governed by a single region in which the automatic rhythm is more rapid than in other parts of the heart. This specialized region, the pacemaker or sino-auricular node, is located in the wall of the right auricle at the point where the venae cavae enter. The impulses which arise there cause the auricle to contract, but impulses do not pass directly from the muscle of the auricle to that of the ventricle. To effect this crossing for the impulse there is a relay located in the wall of the heart at the point where the auricles and ventricles join. This relay or bridge, the so-called auriculo-ventricular node, is a small area of specialized tissue which branches down the ventricles. The muscle of the ventricles contracts in response to impulses coming from this relay, which in turn receives these impulses from the contracting auricle. Although the contraction of both auricles and of both ventricles, when an impulse is initiated in either region, is simultaneous, there is a short delay, about 0.02 of a second, in the passage of the impulse from the auricles to the ventricles, so that the contraction of the former is completed before that of the ventricles has commenced.

The Electrocardiogram.

The energy of the impulses, which arise in the pacemaker and travel over the heart muscle causing it to contract, is expended in part as electrical energy. By means of a delicate galvanometer this electrical impulse can be detected and its intensity recorded. The apparatus used is known as an "electrocardiograph." Electrodes wet with salt water and placed on the hands and feet of the subject are connected by wires to a string galvanometer. This instrument consists of a very powerful magnet with the poles shaped like knife edges and brought nearly into apposition. Between the poles is stretched a thread of quartz so fine as to be almost invisible. The thread is plated with gold to

make it a conductor of electricity. The minute current from the heart passing through the "string" deflects it in the magnetic field. A beam of light from a powerful electric lamp casts the shadow of the string through a microscope by which it is magnified upon a moving photographic film. The photographs thus taken are records of the rate, path, and force of the conduction of the impulse of contraction through the heart. This method is used as a means of determining the nature and location of irregularities in the action of the heart.

No two electrocardiograph records taken from normal individuals are precisely alike, but the differences are only in minute detail; the general shape and time relations are universal. Figure 18 shows a

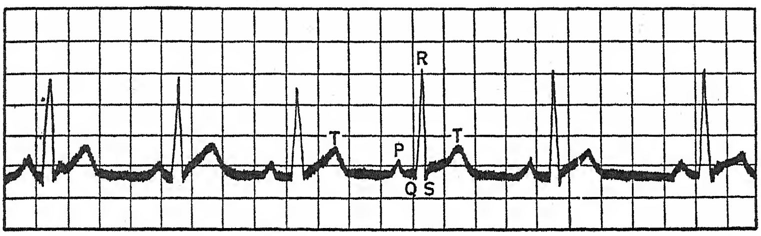


Figure 18. Electrocardiogram Showing Normal Heart Action.

normal electrocardiogram with the various phases marked with the letters generally employed for this purpose. The wavering black line is the shadow of the galvanometer. Between P and T the line is horizontal, showing that the string is stationary. During this time no stimulation passes through the conducting system of the heart; the heart is in diastole. The elevation P covers the period of the auricular contraction; that of Q, R, S, T, the period of ventricular contraction. The time elapsing in the stationary phases of the galvanometer string between P and R is that required for the impulse in the heart to pass from auricle to ventricle.

The precise diagnosis of the many abnormalities in the action of the heart from deviations in the electrocardiogram requires great skill. The brief descriptions of the electrocardiograms given here and in subsequent sections are intended to illustrate general principles only.

Regulation of the Heart Rate.

The conducting system of the heart regulates and integrates the activity within the heart, but it does not regulate the rate of the heart's action to the body's need for blood. This regulation is under the con-

trol of nerves. There are two systems of nerves running to the heart and terminating in the region of the sino-auricular node. One set is made up of branches from the vagus nerves. These nerves start from the brain and run down the sides of the neck directly behind the carotid artery. These arteries can be felt, one on each side of the neck, when the finger tips are pressed into the space behind the windpipe. The other set of nerves is made up of branches from the sympathetic nervous system; they arise from cells in the spinal cord. The action of the vagi and sympathetic nerves are in antagonism; impulses from the vagi tend to slow the heart rate; those from nerves from the sympathetic system to hasten it. Impulses are sent through both sets of nerves continuously; when the impulses from the vagi are increased the heart rate is slowed; when they are decreased, or when those from the sympathetic fibers are increased, the heart rate is accelerated. It is through the action of these two sets of nerves that the heart rate is increased during emotion or physical exertion and slowed during emotional calm and rest. It is probable that the nerves do not act directly upon the heart muscle or sino-auricular node, but indirectly by the formation of stimulating or depressing chemical substances at their ends. It is probable also that internal secretions formed elsewhere in the body may exercise some control over the rate of the heart. The vagus nerves send branches to the lungs, stomach, and intestines as well as to the heart. When the intestines or stomach are struck, nerve impulses are sent to the vagus center in the brain, and through a reflex the heart may be influenced. Thus a severe blow on the abdomen may cause the heart to slow down to such an extent that unconsciousness is produced. One of the "knock-out" blows used by pugilists is that to the pit of the stomach; the even more effective "blow below the belt" is forbidden.

Pulse and Its Rate.

The rate of the heart is most conveniently determined by counting the pulsations which are felt when the finger is placed over an artery near the surface of the body. Each pulsation corresponds to a beat of the heart. The artery commonly examined is the radial, which runs along the under surface of the wrist on the same side as the thumb. The index finger is used to feel the pulse, never the thumb, for it has a small artery near its tip which on pressure may sometimes be felt and mistaken for the pulse to be examined. A graphic record can be taken of the pulse by an instrument which presses on the artery,

and through a system of levers transmits its movements, in magnified form, to a pen writing on a revolving drum covered with a strip of paper.

The pulse in an artery is a wave which passes over the blood in the vessel. This wave, a sudden increase in pressure and velocity of the blood in the arterial system, is caused by the contraction of the heart. The pulse wave moves at a much greater velocity than does the flow of blood in the vessels. A similar movement may be caused in a stream of water when a stone is thrown in; the wave formed may travel at a greater rate than the flow of the water downstream. The velocity of the blood in the larger arteries is about half a meter a second; the pulse wave travels some twenty meters in the same time. The pulses felt in the vessels at different distances from the heart are, therefore, not synchronous. By placing a finger of one hand over the pulse of the opposite wrist and at the same time pressing a finger of the latter hand against the carotid artery of the neck, a distinct lag can be detected in the pulse of the wrist.

The so-called normal pulse rate is taken under conditions of rest and freedom from emotional excitation. The rate varies somewhat with the size of the individual. The pulse rate of small animals is much more rapid than that of large; thus the mouse and the canary have rates of 1000 beats per minute; the dog about 100, the sheep 70, and the elephant 25. The human infant has a rate of about 130 per minute. The rate decreases progressively until adolescence when the adult rate is reached. The average for adult human beings is 70 per minute, but this average does not signify an absolute normal. The extremes of normal pulse rates may extend as low as 50 or 60 to as high as 80 or 90 per minute. The use of tobacco and coffee tends to increase the pulse rate; muscular training, as of the athlete, to lower it. Young athletes not infrequently have a pulse rate between 50 and 60. This fact, however, does not signify that a pulse rate of 80 for a sedentary individual is abnormal, or in any way incompatible with good health.

Exercise causes a prompt increase in the pulse rate, for an increased circulation is needed to bring an abundance of blood to the working muscles. The pulse rate may rise to 170 or 180 beats per minute; higher rates are less effective in pumping the blood, for the heart does not have time to fill during diastole. Rates of 200 beats per minute, or even higher, occur in untrained men (especially those who smoke much) during vigorous exertion; they also occur in severe fatigue. After the

exercise is stopped, the increased rate does not for a time return to normal; the length of the delay depends upon the physical state of the person—the sooner it returns, the better. When the emotions are aroused the rate of the heartbeat is increased, although no greater supply of blood is needed by the body; the acceleration may be considered as being in anticipation of the muscular exertions which frequently follow emotions such as fear and anger; similar anticipatory changes occur in the mobilization of sugar within the body. When the temperature of the body rises above normal, as in fever, the pulse rate is also increased. Thus an accelerated pulse is one of the signs of fever.

The pulse rate is often slowed during jaundice, and even more so as a result of injuries causing fracture of the skull. When the pressure within the skull, and hence upon the brain, is increased, the heartbeat is usually slowed through the stimulation of the vagus nerves. The increased pressure in fracture of the skull results from rupture of a blood vessel with hemorrhage in or about the brain. The operation of trephining, boring a hole in the skull, is performed to relieve the pressure. In some fractures of the skull the hemorrhage escapes through the break in the bone and bleeding occurs at the ears or nose. It is unwise to attempt to stop this type of hemorrhage, for its continuation prevents an accumulation of the blood within the skull.

Irregularities of the Heartbeat.

A common type of irregularity in the rhythm of the heart occurs in children with normal hearts; it is known as respiratory arrhythmia. The fluctuations in rate follow the breathing; during inspiration the rate becomes more rapid, but slows down during expiration. With each breath the cycle is repeated. In this type of arrhythmia the nervous impulses from the lungs reflexly influence the vagus center causing the cyclic changes in the heart rate. Respiratory arrhythmia is a normal phenomenon.

The nerves to the heart may modify the rate at which it beats, but they do not affect the mechanism of the beat. Disturbances may, however, arise in the conduction of the impulse through the heart muscle, so that irregularities appear not only in the rate, but in the mechanism of the beat as well. The most common disturbance of this type is the so-called premature beat or extrasystole. An extrasystole is a beat which interrupts an otherwise regular heart action by occurring prematurely. When the pulse of a person in whom extrasystoles occur is felt, an

occasional pause is noted, followed by a forceful impulse. Two beats close together precede the pause; the second of these beats is weak because the heart has not had time to fill properly. The beat after the pause is forceful because the heart has filled to an unusual extent. Most premature beats of the heart originate from some part of the heart other than the normal pacemaker; some area momentarily rises to a sufficient degree of excitability to act spontaneously, and in so doing sets off the train of contraction in the ventricle. The impulses arising from the pacemaker continue in normal timing; but since for a brief period after the premature contraction, or after any other contraction, the heart muscle is incapable of responding to stimulation,

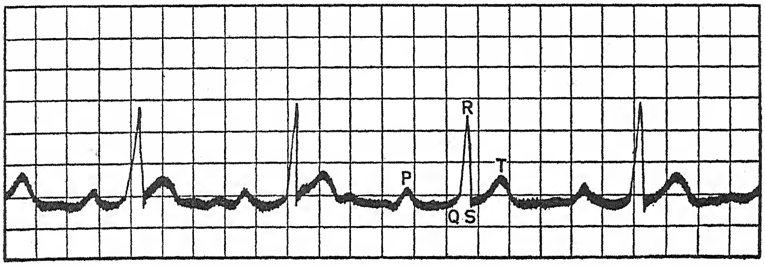


Figure 19. Electrocardiogram Showing Delayed Conduction.

the impulse from the pacemaker falls upon this refractory period. The normal beat is omitted, and a relatively long pause occurs. The extrasystole causes no more than the normal number of beats at any time, for while one, a weak premature contraction, is gained, another is lost.

Extrasystoles are abnormal; their presence indicates the action of some disturbing influence upon the muscle of the heart. They are not, however, an alarming condition, for they may be produced by many factors, some of which are temporary. Tobacco and coffee in excess are common causes. The action of either substance seems to be heightened by lack of sleep, nervous strain, or dissipation. Extrasystoles frequently occur in diseases of the heart muscle and in chronic high arterial pressure; but they are not indicative of these conditions.

Figure 19 is from an electrocardiogram showing the disturbance known as delayed conduction. In every respect except one this electrocardiogram appears normal; the exception is in the space between the end of the P wave and the beginning of the R wave. The time required for the impulse to pass from auricle to ventricle is abnormally long. In the normal heart the interval does not exceed 0.02 sec-

ond; here it is more than 0.03. Conduction is delayed. This condition may be a stage in the development of a more serious condition known as heart block in which conduction from auricle to ventricle may fail entirely. The auricle then beats at a normal rate under the control of the pacemaker, but the impulses are not transmitted to the ventricle. The ventricle therefore drops its rhythm to the spontaneous contraction rate of its muscle. This rate is 30 to 35 per minute. Exercise, or any other factor which normally affects the rate of the heart, ceases to have any influence upon the rate at which the ventricle contracts. The heart makes no response to the varying needs of the body for blood. Those afflicted with heart block may therefore faint when they attempt exertion, for the extra blood flow to the muscles robs the brain of its sup-

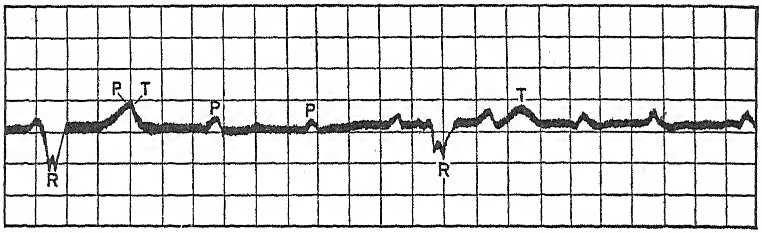


Figure 20. ELECTROCARDIOGRAM SHOWING HEART BLOCK.

ply. In childhood heart block may occur as a serious complication of diphtheria or rheumatic fever; in middle age it is often due to syphilis; and after fifty, hardening of the arteries in the heart becomes the main cause. In many instances the heart block is incomplete, so that impulses from the auricle are passed to the ventricle but only in an imperfect manner. Figure 20 shows the electrocardiogram from a case of complete heart block; the auricle, the P wave, beats at the rate of 96 per minute; the ventricle, at 20 per minute.

A common irregularity of heart action, and one usually with serious significance, is known as auricular fibrillation. An electrocardiogram from this condition is shown in Figure 21. The auricles of the heart are dilated; they fail to beat, but they constantly send out a series of impulses marked here as f waves. Their rate is some 500 per minute. The ventricle, bombarded by the impulses, cannot respond to all, but only to occasional ones almost at random with contractions that are sometimes weak, sometimes strong. The pulse is irregular in both rate and force. Auricular fibrillation may occur as the result of damage to the heart muscle from rheumatic fever; in individuals past fifty it may occur from hardening of the arteries which supply the heart.

Figure 22 shows the electrocardiogram of a heart irregularity that is almost invariably fatal. It is known as ventricular fibrillation. The ventricle here is not contracting, only quivering; it does not pump blood. Ventricular fibrillation is a common behavior of the heart at death from many conditions. It is a common cause of fatality in electric shock. An electric current passed through the body follows the

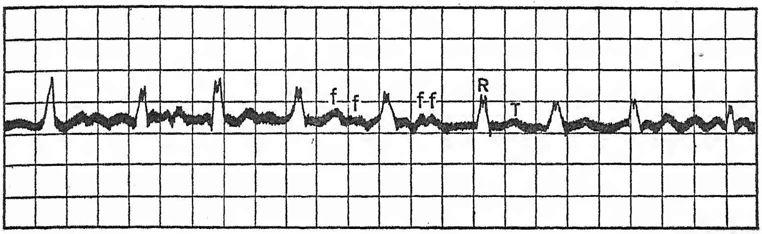


Figure 21. Electrocardiogram Showing Auricular Fibrillation.

path between the points where contacts are made with the body. If it passes from leg to leg it may cause pain, injury to the legs and severe burns, but it does not reach the heart for this organ does not lie in the path of the current. When, however, the current is applied to the feet and the hands, or to the two hands, the heart does fall in the path.

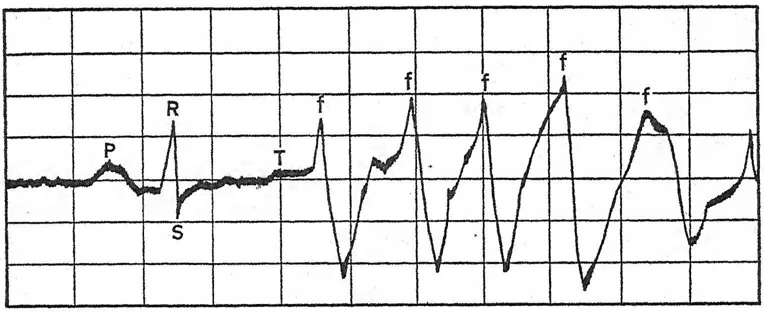


Figure 22. Electrocardiogram Showing Ventricular Fibrillation.

If the current is sufficiently strong the ventricle fibrillates and death results.

There are few authentic records of the human heart ever recovering from ventricular fibrillation. Recovery, however, is common in small animals, such as the rat, after experimental electric shock; the smaller the heart, the greater the possibility that, by chance, half or more of the heart fibers will move in unison and so make a true contraction.

Laboratory methods have been developed for completely stopping the heart in ventricular fibrillation and then starting it again in normal beat. In the accident of electric shock the time between fibrillation and death is too short for the practical application of such methods.

Infection of the Heart.

In young people infection is the main cause of heart disease, especially of the variety known as valvular disease. Heart disease developing after middle age is due largely to hardening of the arteries which supply the heart muscle. Heart disease is the leading cause of death both in the young and in the old.

Injury from infection may affect different parts of the heart; thus the toxin of diphtheria acts on the heart muscle; the organism causing syphilis on the aortic valve; the virus of rheumatic fever on both the muscle and the valves, especially the mitral, and sometimes the pericardium as well; the streptococcus viridans acts upon the lining of the heart, the endocardium.

Before the introduction of diphtheria antitoxin for treatment and toxin-antitoxin for prophylaxis, diphtheria was a common disease. One cause of its fatality was heart failure. The toxin absorbed from the diphtheria bacilli growing under the membrane formed in the throat killed the fibers of the heart muscle. The injured muscle ceased beating. Sometimes death from this cause occurred suddenly after the acute stages of the disease had passed.

More common than diphtheritic heart disease in the past, and vastly more so today, is heart disease caused by syphilis. The organism of syphilis acts primarily upon the aorta, but the damage may extend so close to the heart as partially to obstruct the openings of the coronary arteries, thus interfering with the nourishment of the heart. It may also involve the aortic valve, stiffening and distending it so that it leaks. Syphilis thus becomes one of the two great causes of chronic valvular heart disease, but, unlike rheumatic fever, the other and now common cause, syphilis rarely affects any valve except the aortic, causing aortic insufficiency. Usually fifteen to twenty years of chronic infection are required before the symptoms of syphilitic heart disease develop. The damage caused by syphilis is irreparable, but the disease is preventable and in its early stages curable. When syphilitic heart disease occurs it usually becomes manifest between the ages of thirty and forty. Rheumatic heart disease, on the other hand, usually develops before twenty.

Rheumatic Heart Disease.

Rheumatic fever is an illness of the whole body with many and widely different manifestations; its one constant feature is its injury to the heart. The commonest effect of the disease on parts of the body other than the heart is inflammation of the joints with pain and swelling; hence the names given to it: rheumatic fever, rheumatic disease, and acute inflammatory rheumatism. The inflammation of the joints leaves no permanent effects. Sometimes the joint pains are not severe, and sometimes they are no more than a vague ache which parents are apt to dismiss as "growing pains" in the erroneous belief that growth causes pain from the stretching of muscles and ligaments. At times the joint pain is lacking, and the main evident symptoms of the rheumatic disease come from the nervous system as chorea or St. Vitus's dance, which results in muscular incoordination and muscular spasms. Chorea rarely leaves any permanent injury to the brain or nerves.

The course of rheumatic fever is wholly unpredictable. Sometimes the damage to the heart muscle and valves is sufficient to cause the heart to fail within a few weeks or months after the onset of the disease. Sometimes the disease disappears after a brief attack, leaving little damage and never recurring. More often, however, the attack causes permanent damage to the heart. Sometimes the disease comes and goes with remissions and exacerbations over years, each attack adding to the damage to the heart. Individuals reaching adult years with the characteristic signs of rheumatic heart disease, mitral stenosis and mitral insufficiency, occasionally live on to the seventies and eighties; by far the greater number die before forty-five.

The disturbances in the heart and in other parts of the body produced by rheumatic fever result from a tissue reaction to some infective agent not yet discovered. Small areas of inflammation are produced. Lumps develop in the inflamed areas; they become infiltrated with migrating cells and eventually heal, leaving scars. These lumps may occur in any part of the body to give the varied symptoms of the disease, but it is only in the heart that they cause permanent damage. The heart muscle is scarred and weakened; the valves are misshapen.

Although the organism or virus causing rheumatic fever has not been isolated, the disease has all the appearances of an infection. There is fever and an increase in the number of white cells; there is also anemia. Often two or more children in a family are affected at the same time. There is much evidence to support the belief that the

organism responsible for rheumatic fever is one of the many varieties of streptococcus. The disease usually occurs or recurs eight to fifteen days after streptococcus tonsillitis. It is far more prevalent in temperate than in tropical or subtropical regions; a similar distribution occurs in other diseases known to be caused by the streptococcus, such as scarlet fever. It is also believed that rheumatic fever develops only in certain susceptible individuals. The cause for the susceptibility is not known; possibly it is heredity. There is no known cure for rheumatic fever and no prevention except residence in a warm climate. Rest in bed minimizes but does not prevent the damage to the heart.

Rheumatic fever affects some 2 to 4 per cent of the population. It is rare under the age of three; it increases in frequency until fifteen, and thereafter decreases slowly to twenty-five and rapidly to forty-five.

Subacute Endocarditis.

The diseases known as acute and subacute bacterial endocarditis are more rapidly fatal than rheumatic fever. Acute bacterial endocarditis occurs as an unusual but serious complication in the course of such infections as pneumonia, erysipelas, meningitis, influenza, and gonorrhea. The organism causing these diseases extends to and infects the heart. The course of the acute endocarditis is usually rapid and fatal.

Subacute bacterial endocarditis rarely affects normal hearts, but only those that have been previously damaged by rheumatic fever. In the great majority of cases the organism infecting the heart is the streptococcus viridans, so called because it produces a greenish color when grown on laboratory culture media containing blood. This organism is a common inhabitant of decayed and abscessed teeth. When the streptococcus viridans infects the heart, ulcers are produced on the heart valves and masses of bacteria and clotted blood collect over them and project out into the chambers of the heart. Portions break off and are carried in the blood stream to other organs, setting up additional foci of infections. There is fever and anemia, but the disease, in spite of the rapid growth of the bacteria in the heart, progresses slowly, usually lasting many months.

Valvular Heart Disease.

Damage to the heart valves causes characteristic changes in the circulation of the blood of essentially the same sort as would occur in the pumping of fluid by any mechanical pump similarly deranged. The

capacity of the heart to pump blood is diminished. The normal heart is able to supply a flow of blood sufficient for the body's needs during violent exercise; consequently during rest or moderate exertion the heart has a large reserve force. When the valves and muscle of the heart are damaged by disease, this reserve force is encroached upon. A heart with a leaky valve in a man sitting at rest may be making as great an effort to support the circulation as would a normal heart during moderate or even violent physical exertion.

The heart tends to compensate for its injuries by growing heavier, enlarging. So long as the reserve force and the changes in the heart itself are sufficient to maintain a circulation adequate for ordinary exertions, the diseased heart is said to be compensated. No particular ill effects arise from such disease until the compensation fails. Many individuals with valvular disease of the heart, often with severe restrictions to physical exertion, live to old age. In many more, however, the disease becomes progressively worse, and a time may be reached when the entire reserve force of the heart is required for its action even in bodily rest. Beyond this point the heart, although doing its maximum of work, is no longer able to supply a normal circulation.

Shortness of breath after moderate exertion, such as walking up a flight of stairs, is usually one of the first symptoms of valvular heart disease. An increase in the volume of air breathed after exertion is normal; but panting and shortness of breath come only after vigorous exertion. Breathlessness is to a large extent dependent upon inability of the heart to increase the flow of blood, and its transportation of oxygen, in proportion to the muscular exertion of the body. A man with valvular disease responds to mild exertion as a normal man would to vigorous exertion. In severe valvular disease breathlessness resembling asthma may occur without any particular exertion. In still more severe cases the breathlessness is continuous; it is aggravated by lying down. Such persons are forced to sleep sitting up.

The inability of the weakened and overworked heart muscle to carry the burden of the circulation results in what is known as congestive heart failure. This is the usual mode of death, not only in valvular disease, but in all forms of heart disease. Breathlessness is one feature of congestive failure, but other indications of inadequate circulation also appear. Blood is dammed back in the liver and the congestion causes this organ to swell. The kidneys fail to carry out their function properly; fluid collects in the tissue of the legs, or other parts of the body, to cause edema or dropsy. The skin may appear bluish

from lack of oxygen in the blood; this is called cyanosis. With rest in bed to minimize the burden on the heart, with restriction of fluid in diet, and with the use of medicaments that stimulate the heart muscle and slow the heart rate, the heart may gain strength and the symptoms of failure pass. The individual may then, for a time at least, carry on a life of restricted activity. But the heart, instead of responding to rest and treatment, may also, as must eventually happen, fail and stop.

Disease of the Coronary Arteries.

The muscle of the heart does not derive its nourishment directly from the blood in its chambers. Instead, like all other muscles of the body, it is permeated by capillaries which are supplied by arteries, in this case the coronary arteries. At the beginning of the aorta, where it bulges slightly to make room for the aortic valve, there are two openings leading to the right and left coronary arteries. These vessels extend over the surface of the heart, giving out numerous branches. After passing through the capillaries the blood is collected into veins which discharge into the right auricle.

Hardening of the coronary arteries results in gradual constriction of the vessels, with diminished blood supply to the heart muscle. The starved muscle is weakened; fibrous tissue like that of scars replaces the muscle fibers. This condition is called chronic myocarditis. It may develop slowly for many years before the reserve of the heart is encroached upon sufficiently to cause breathlessness on slight exertion. Eventually, with continued degeneration, the starved muscle will fail in one of two ways: the nearly painless congestive failure described in the previous section, or a painful type called anginal failure or angina pectoris.

Angina Pectoris.

Angina pectoris, which means pain in the chest, is not a specific disease of the heart; it is merely one of the manifestations of curtailed blood supply to the heart. The heart limps painfully just as do the legs when their arteries are constricted by arteriosclerosis, syphilitic arterial disease, or Buerger's disease. It is believed that in some cases the typical symptoms of angina pectoris are produced, not by arteriosclerosis alone, but by additional constriction of the vessels due to nervous action much as those of the hands and feet may be constricted in Reynaud's disease.

Contrary to common belief, angina pectoris does not always cause

sudden death. Sudden death may occur, but more often those with the disease live for several years but with recurrences of the painful attacks.

The pain of angina pectoris is not as a rule felt over the heart itself; pain there may come from rheumatic fever, high arterial pressure and especially nervous disorders that have no fatal consequences. The pain of angina pectoris is referred (see page 349). Usually it is felt beneath the lower part of the breastbone, often radiating from there to the left side of the neck and shoulder and down the left arm. The pain may last for only a few minutes, but is agonizing in its intensity. Frequently the attacks of the disease are precipitated by exertion or some strong emotion like anger. They can be prevented only by remaking the whole mode of life emotionally and physically to lessen the burden on the heart to correspond to the diminished blood supply. The attacks of the disease can be shortened and pain relieved by the use of drugs that relax the arteries. The commonest one used for this purpose is nitroglycerin in small amounts.

No medicinal or surgical measures can repair the damage to the coronary vessels, but it is sometimes possible to relieve the burden on the heart and even to increase the circulation to the heart muscle. Pain from the heart is carried in nerve fibers of the sympathetic system; these are sometimes cut to relieve the pain. The thyroid gland may be removed to lower metabolism and hence lighten the work of the heart. And finally, in the effort to prolong life the heroic operation of grafting a flap of muscle from the chest on to the heart has been tried with some success. The blood supply of the heart muscle is increased by vessels which grow out from the adherent muscle.

Coronary Occlusion.

The slowly developing process of coronary sclerosis, which in turn leads to chronic myocarditis or angina pectoris, may be interrupted at any stage by what is known as coronary occlusion. The occlusion is usually caused by a thrombus which forms on the roughened walls of the artery. The thrombus suddenly shuts off the supply of blood to a portion of the heart muscle. There is usually immediate and excruciating pain resembling that of angina pectoris. It may last for hours or days. The outcome depends upon how seriously the heart muscle is damaged. In some 20 per cent of cases, death occurs within a few hours. In the remaining 80 per cent the portion of the heart muscle deprived of blood is converted into scar tissue and weakened. Approxi-

mately one-quarter of all individuals with hearts so affected die within a year, either from a second attack of thrombosis or from failure of the weakened muscle. A few individuals recover from coronary occlusion nearly completely and live normal lives for ten or fifteen years, even longer, after their attack. Coronary occlusion is a disease that is increasing in prevalance especially among business and professional men. Most cases occur between fifty and sixty years of age; angina pectoris and chronic myocarditis, after sixty.

Nervous Disorders of the Heart.

Disturbances of the heart are divided for convenience of description into two groups, organic and functional. In organic disturbances there is actual damage to the heart, as in valvular disease or sclerosis of the coronary arteries; in functional disturbances the heart is organically sound but its action is deranged, as in the occurrence of extrasystole. Functional disorders include also all nervous disturbances with symptoms which, in the mind of the individual affected, give rise to the belief that the heart is diseased. Such disturbances are called cardiac neuroses. They occur usually in individuals of anxious temperament who, under the stress of their anxiety, sometimes think they are afflicted with physical disease. Often the fear thus engendered seems to supply its own proof. The heart responds to emotion; its rate may be speeded up, pain may occur over it and its beat may be felt with abnormal intensity. The symptoms from a cardiac neurosis often bear no similarity to those from actual disease of the heart, but the erroneous belief that they are caused by heart disease is none the less distressing to the individual affected. The belief may influence his activities to the extent even of near invalidism. The condition is sometimes relieved if, after thorough examination, the individual can be convinced that his symptoms are due to something other than his heart; more often it is necessary to uncover the fundamental psychic disturbance that is responsible.

The Lymphatic System.

The cells of a tissue do not form a compact mass. Between them there are irregular spaces filled with a colorless tissue fluid; it is in this medium that the cells of the body live. This fluid is essentially the same as the much larger collection known as the cerebrospinal fluid that fills a cavity in the brain and surrounds the spinal cord; it is essentially the same also as the aqueous humor which fills the front

part of the eyeball, and the serous fluid which is present, in small amount, in the pericardial sac and on the surface of the peritoneum. The same type of fluid, when present in a series of vessels, the lymphatics, to be discussed here, is known as lymph. Indeed, the term lymph may, with little departure from strictest accuracy, be applied indiscriminately to lymphatic fluid and tissue fluid. In composition it resembles blood serum but contains much less protein.

The cells of the body derive their nourishment from the tissue fluid about them and discharge their waste products into it. The tissue fluid is continually renewed by the passage of water and dissolved substances from and into the blood stream. This passage is effected mainly

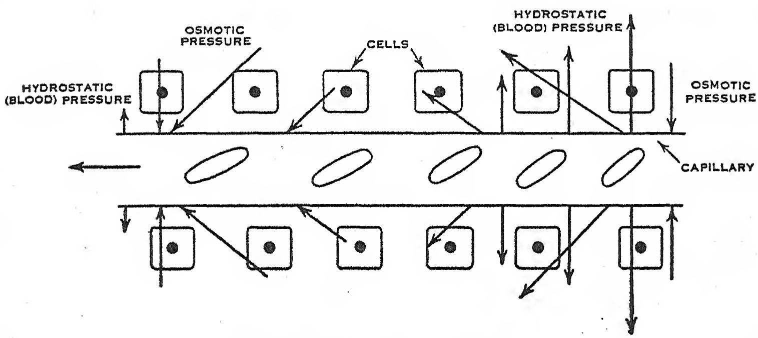


Figure 23. Formation of Lymph.

by filtration, osmosis and diffusion. Filtration is the process by which fluids and substances dissolved in them pass through a membrane, such as the walls of the capillaries, by virtue of a difference in pressure. Osmosis is the process by which fluids are attracted through a semipermeable membrane, again such as the walls of the capillaries, from solutions of low to solutions of high concentrations. Diffusion is the process by which dissolved substances pass through a membrane by reason of their difference in concentration on the two sides of the membrane.

The operation of these processes can be followed during the passage of the blood through a capillary. Water, salts, sugar, amino acids, and dissolved gases can pass through the walls of a capillary, but proteins cannot, or at most, to only a slight extent. Since the concentration of proteins is higher in the blood than in the tissue fluid, the proteins of the blood exert an osmotic pressure that tends continually to draw

fluid into the blood through the walls of the capillaries. This osmotic pressure is directly opposed by the mechanical pressure of the blood within the capillaries which tends to force fluid through the walls by the process of filtration. During the passage of the blood through the capillary this mechanical pressure falls off considerably; the osmotic pressure is little affected. Thus the pressure relations are such that in the first part of the capillary the mechanical pressure exceeds the osmotic pressure and fluid is filtered out into the tissue spaces; in the last part of the capillary the falling mechanical pressure is exceeded by the osmotic pressure and fluid is drawn from the tissue spaces into the capillaries. Through the full length of the capillary dissolved substances diffuse through the walls in directions determined by the differences in concentrations in the blood and tissue fluid.

The outflow of fluid through the walls of the capillaries is slightly in excess of the inflow. A special set of vessels, called the lymphatics, operates as needed to prevent excessive accumulation. Minute vessels resembling capillaries ramify through the tissues. These vessels unite to form larger vessels which extend toward the chest. There they empty into the veins near the heart. Any excess of fluid in the tissue spaces passes into the lymphatics and is carried through them and discharged into the blood stream. The lymphatic vessels are equipped with valves; the passage of lymph is effected largely by a pumping action brought about by the compression and relaxation of the lymphatics during muscular movement. When the muscles are stationary tissue fluid tends to accumulate, as may be seen in the swelling of the ankles after standing with the legs held stationary. The swelling does not occur during walking since the muscular movement pumps the fluid through the lymphatics. Massage is likewise effective in causing a movement of lymph.

In all parts of the body, with the exception of the lower part of the diaphragm, the lymphatic capillaries are closed at their extremities. Fluid probably enters them in much the same way that it does the blood capillaries. In the upper part of the abdomen, because of the special arrangement of the lymphatics of the diaphragm, the absorption of fluid is especially rapid. Consequently when infected fluids are present in the abdomen, as in peritonitis, the surgeon often raises the patient in the bed so that the fluids collect in the lower part of the abdomen where they are absorbed more slowly.

Not only fluid, but minute solid particles as well, may pass into the lymphatics; the passage is probably assisted by white corpuscles which

engulf the particles and then penetrate the lymphatics. Bacteria infecting a tissue, and also cancer cells broken off from a cancerous growth, may thus enter the lymphatics and be carried in the stream of fluid.

Lymph Nodes.

There is an advantage in the fact that bacteria from an infected area enter the lymphatics rather than the blood capillaries. The lymph

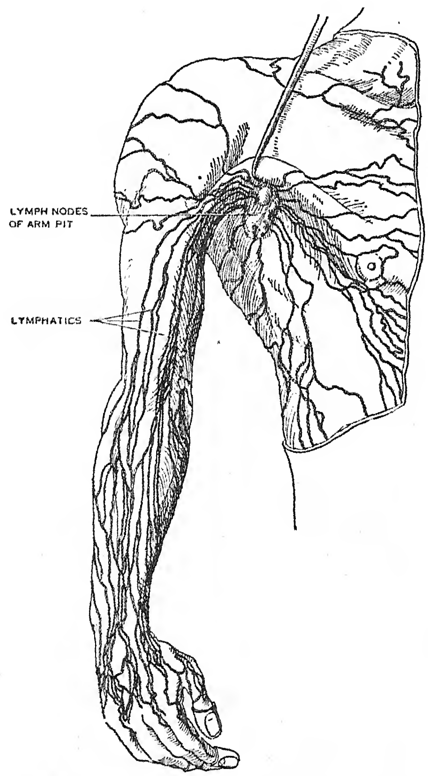


Figure 24. LYMPHATICS OF THE ARM AND CHEST.
The hook shown draws back the muscle to expose the lymph nodes of the arm pit into which the lymphatics of the arm and chest empty.

flows finally into the blood in the veins near the heart; but before it has thus emptied, it passes through structures which serve as filter stations in retaining and destroying foreign particles that the lymph may contain. These structures are known as lymph glands or nodes. The blood is not similarly freed of foreign solids. One variety of

white blood cells, the lymphocytes, are formed in the lymph glands; they are capable of engulfing bacteria. When a lymph node retains bacteria it frequently becomes swollen and painful. A sore throat or tonsillitis is followed by swelling of the lymph nodes in the neck; severe infection of the hand may bring into prominence a group of glands in the armpit; infection of the foot, leg, or genital organs similarly affects the glands in the groin. In severe infections, careful inspection may show a narrow pink streak, an inflamed lymphatic, extending from the point of infection on the hand or foot to the lymph node in the armpit or groin.

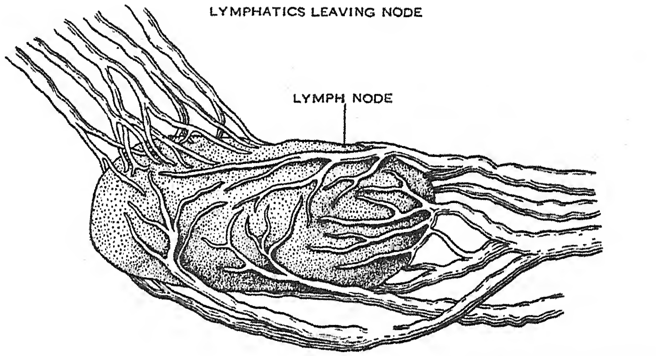


Figure 25. LYMPH NODE.
Showing lymphatics entering and leaving.

Under these circumstances the surgeon tries, as in the case of abdominal infection, to slow the absorption from the infected area; he does so by keeping the arm or leg at rest to avoid movement of lymph from muscular movement. Likewise massaging of an infected region is carefully avoided.

There are lymph glands about all of the internal organs; thus in pulmonary tuberculosis those of the lungs situated near the bronchial tubes are affected. The particles of carbon from coal dust and smoke which are inhaled also collect in these nodes.

Bacteria which have been stopped by a lymph node sometimes cause an acute inflammation of the node. Pus then collects and an abscess forms. Tubercular abscesses in the glands of the neck sometimes occur in children. The bacteria are absorbed from the mouth or throat, are stopped by the glands in the neck, and the tubercular infection centers there. It may then be necesary to remove the gland by surgical

operation. When the lymph glands are unable to cope with the bacteria which reach them, the organisms escape into the blood stream, giving rise to septicemia, commonly called blood poisoning.

Cancer cells which are filtered out by lymph glands grow in the glands, making them a center for a new cancer. It is the practice in operating for cancer to remove not only the primary growth, but also the lymph glands through which the locality is drained. Thus in removing a cancer of the breast the glands in the armpit are also removed.

Tonsils.

The lymph glands located beneath the mucous membrane of the throat are spoken of as tonsils. There are a number of these glands,

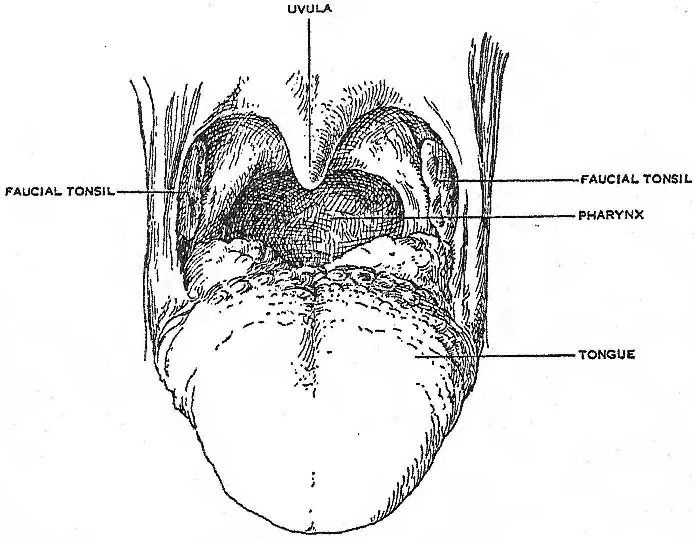


Figure 26. Faucial Tonsils.
The faucial tonsil on each side of the throat occupies a space between the vertical folds of flesh which run together into the soft palate. The adenoid tonsil is shown in Figure 7.

but unless they are abnormally swollen only a few are evident. The most prominent are a pair, the faucial tonsils, occupying a space on each side of the throat between the vertical folds of flesh which run together to form the soft palate. The pharyngeal tonsil, or adenoid, is located on the back wall of the nasal pharynx, the passage leading from the nose to the throat. This gland is particularly prominent in

children. Enlargement of the adenoid may obstruct the passage from the nose to the throat and cause mouth-breathing; if the condition persists for a long time, deformity in the development of the nasal passages and upper jaw may result. A less definite collection of lymphatic tissue, the lingual tonsil, occurs near the base of the tongue. This may become swollen as a result of irritation by tobacco smoke, causing the chronic cough often associated with cigarette smoking. The lymph nodes beneath the mucous membrane about the openings of the Eustachian tubes may become swollen as a result of a cold in the head. Temporary impairment of hearing results from the closure of the tubes.

In childhood all of the lymphatic tissue of the body is relatively large; the tonsils and adenoids may be very prominent. After middle life the normal tonsil does not rise above the surface of the mucous membrane, and therefore is not apparent. The size of the projecting portion of the tonsil does not indicate the size of the mass which may be buried under the mucous membrane.

Infection of the Tonsils.

The faucial tonsils have a particular significance in that they are a common site of local infection and a common entrance for general infection. When acutely infected, the tonsils appear red and swollen; usually they are painful, especially so in adults. The outer surfaces of the tonsils are irregular; the mucous membrane which covers them folds into pits and crypts of various sizes. During infection the crypts may retain secretions and dead white cells, becoming filled with a malodorous cheese-like material. These collections show as small white spots that appear to dot the surface of the tonsil.

The tonsils may become inflamed from irritation, as in excessive smoking, but the severe inflammation with general illness results only from bacterial infection. In the great majority of instances, if not in all, the organism causing the infection is one or another of the many varieties of streptococci. The severity of the infection and the character of the symptoms exhibited depend upon the nature of the streptococcus present and also upon the degree of immunity of the individual affected. Some strains of streptococci cause the comparatively mild acute tonsillitis; others, the severe and sometimes fatal septic sore throat; and still others, scarlet fever with its peculiar skin rash. Some individuals are virtually immune to such infections and others are highly susceptible.

The organisms causing tonsillar infections are conveyed in the secretions from the nose and mouth, and are transmitted by "contact." Droplets may be sprayed to other persons in talking, sneezing, or coughing, or the secretions may contaminate food or articles of common use, such as towels, dishes and glassware, or pass from hand to hand. All articles, especially dishes and glasses, used by anyone with tonsillar infection should be sterilized by immersion in boiling water or a disinfectant before being used by another person.

The removal of the tonsils may greatly decrease tonsillar infection but does not prevent it entirely. The faucial and adenoidal tonsils, and sometimes the lingual, are the ones removed, but there are many other masses of lymphoid tissue about the throat which may become infected. It is considered unwise to remove the tonsils unless there is good reason for doing so, as indicated by repeated attacks of acute tonsillitis or a chronic state of inflammation. It is believed that in early life the tonsils may assist in the development of immunity to streptococcus infections. Tonsillitis, scarlet fever, and, indeed, all streptococci infections, are of much less occurrence in tropical and subtropical than in temperate regions.

Tonsillitis.

The mild or common tonsillitis tends to occur in epidemics especially in the spring and fall. The disease has an incubation period of one to two days and usually commences with headache, pain in the back and limbs, and a chilly sensation of the skin. Fever develops and the tonsils become red and painful; white spots may or may not show at the mouths of the crypts. The acute stage of the disease lasts three to five days and is ordinarily followed by complete recovery. The infection is occasionally complicated by an extension of the infection into the middle ear, the mastoid bone, or the sinuses. In the last locality it may become chronic. Occasionally pus forms beneath and about the tonsil as an abscess, a condition known as quinsy.

Septic Sore Throat.

The tonsillar infection known as septic sore throat is much more severe than simple tonsillitis. Frequently the source of infection is milk containing streptococci. These organisms enter the milk from an infection in the udder of the cow. The infection there is usually derived from a dairy attendant who is a carrier of the streptococci or is convalescing from tonsillitis. From its growth in the cow the organism

appears to gain virulence. The general symptoms of septic sore throat resemble those of simple tonsillitis but are much more severe, the temperature frequently rising to 104° or 105°. The outstanding peculiarity of the disease—from which it derives the name septic—is the tendency for the streptococci to spread throughout the body and cause infections in many different parts. The disease closely resembles scarlet fever except for the absence of the skin rash. The mortality of septic sore throat is usually from 3 to 5 per cent; in some outbreaks it may be much higher. The disease can largely be prevented by the use of milk that has been pasteurized.

Scarlet Fever.

The streptococcus that causes scarlet fever is identical in appearance with those that cause simple tonsillitis and septic sore throat; it differs, however, in producing a soluble poison, a toxin, which when absorbed into the body is believed to cause the rash of scarlet fever. An attack of scarlet fever appears to confer immunity against subsequent attacks of the disease, but in reality the immunity is only against the rash-producing toxin. Individuals who have had scarlet fever may at later periods contract severe tonsillitis from those who have the disease, but they do not show the skin rash.

The incubation period for scarlet fever is usually one to two days. The disease commences with the symptoms of a severe tonsillitis, but in a day or two a multitude of minute red spots appear on the skin and also on the tongue, tonsils and throat. In mild cases the temperature begins to drop in five to seven days; the skin rash fades; and the skin of the hands and feet peels off in sheets and shreds, that of the body in scales.

The danger of scarlet fever lies in the complications that may develop during the course of the disease or follow as sequelae. The ear, heart, and joints may be affected; especially dangerous is damage to the kidneys which may develop suddenly two or three weeks after the beginning of the disease.

The severity of scarlet fever varies from year to year in the different epidemics; its mortality also varies with the age of the individual affected, being highest for infants and young children.

The susceptibility of an individual to scarlet fever can be determined by injecting into the skin a small amount of the toxin obtained from the streptococcus causing this disease. In the absence of immunity to the rash-producing toxin a red spot develops at the site of the injection.

This procedure is known as the Dick test and is not to be confused with the Shick test used to determine susceptibility to diphtheria. Sera containing an antitoxin which is effective as an antidote for the rash-producing toxin of the streptococcus have been used in treating scarlet fever.

Diphtheria.

Diphtheria is not a form of tonsillitis since it may affect any portion of the throat and nasal passages or any wound on the surface of the body. It commonly occurs on or near the tonsils; and since early treatment with diphtheria antitoxin may save life, prompt differentiation from tonsillitis is essential. Diphtheria is caused not by the streptococcus but by a rod-shaped organism, a bacillus, in this case the diphtheria bacillus. The growth of the organism on the surface of mucous membrane is followed by the development of a sheet of coagulated serum as a pseudo-membrane. The bacteria growing under the membrane produce a toxin which is absorbed into the blood, causing a poisoning throughout the body.

Diphtheria has an incubation period of two to five days. At the onset the symptoms are usually less severe than those of simple tonsillitis. The child affected does not appear particularly ill; the temperature rarely rises above 102°. The tonsils at first appear red, but soon small yellowish spots appear, and these, as they expand, fuse to form a grayish-colored membrane. Thereafter the membrane may spread rapidly. If diphtheria antitoxin is administered, the growth of the membrane is stopped; in a few days it becomes detached. The antitoxin also brings to an end the fever and other symptoms of the disease.

When diphtheria occurs in the larynx, the membrane may obstruct the windpipe, causing suffocation. It may be necessary then to pass a metal tube down the throat to form a passage for air or even to make an opening in the front of the windpipe, an operation called tracheotomy.

One attack of diphtheria usually confers immunity against the disease; many individuals have a natural immunity. The blood then contains antitoxins which are capable of counteracting the toxin of diphtheria. The presence or absence of immunity can be determined by the so-called Shick test. A small amount of diphtheria toxin is injected into the skin. As in the case of the Dick test for scarlet fever, lack of immunity is shown by the development of a small red area. Temporary immunity to diphtheria may be obtained by injecting into

the flesh serum obtained from a horse which has been given repeated and increasing doses of diphtheria toxin. The serum thus obtained is the diphtheria antitoxin used in treating the disease. A more permanent immunity can be acquired by injecting a small dose of diphtheria toxin neutralized with antitoxin, the so-called toxin-antitoxin immunization. By use of this procedure in children showing a positive Shick test, diphtheria could be virtually eradicated.

Diphtheria is spread by contact. It is possible to isolate and control the spread from those who have the active disease, but, as in the case of typhoid fever, there are carriers of the disease who, while showing none of the symptoms of the disease, nevertheless harbor the organisms in their throats and spread them to others.

CHAPTER VIII

RESPIRATION AND VITAL COMBUSTION

IT IS BY MEANS OF OXIDATION THAT THE ENERGY OF THE FOODSTUFFS IS liberated and made available for work and heat; oxygen is as essential for the vital combustion within the cells of the body as is the fuel afforded by the foodstuffs. The oxidation of foodstuffs results in the formation of carbon dioxide. It is by respiration that the cells of the body obtain oxygen and rid themselves of carbon dioxide. The oxygen is obtained from the air, which contains nearly 21 per cent of this gas; the carbon dioxide is discharged into the air. The cells of the body do not carry out this gaseous interchange directly with the air but only indirectly through the blood. The blood passes through the capillaries of the lungs and there exchanges gases with the air that is alternately drawn into and expelled from the lungs. The blood then circulates to the tissues where it exchanges gases with the cells. The heart pumping the blood around is one of the chief organs of respiration. It is the limiting factor in physical vigor, for the rate at which oxygen can be brought to the tissues is determined, not by the capacity of the lungs to move air, but by the capacity of the heart to pump blood.

The volume of air breathed and the volume of blood pumped at any time are determined by the rate at which combustion is occurring within the cells of the body. The amount of oxygen removed from the blood by the cells and the corresponding amount of carbon dioxide returned vary in proportion with the rate of this combustion. The amount of air that must be passed through the lungs to supply the oxygen and remove the carbon dioxide corresponds to these variations. The variations in the amount of gases transported by the blood between the lungs and tissues involves a corresponding adjustment of the transporting agent, the circulation of the blood. This activity is controlled by the heart. When a man exercises he breathes more air and his heart beats faster.

The lungs consist of a thin membrane folded into a great many small sacs. These sacs open to the external air by way of the bronchial tubes and trachea. Between the folds lies a network of capillaries. As the

capillaries of the lungs form the only path through which the blood flows from the right side of the heart to the left side, all of the circulating blood passes through the lungs at each round of the circulation. In its passage the blood comes into gaseous equilibrium with the air in the lungs; carbon dioxide passes out of the blood and oxygen passes in until the pressures of each gas in the blood and in the air are the same.

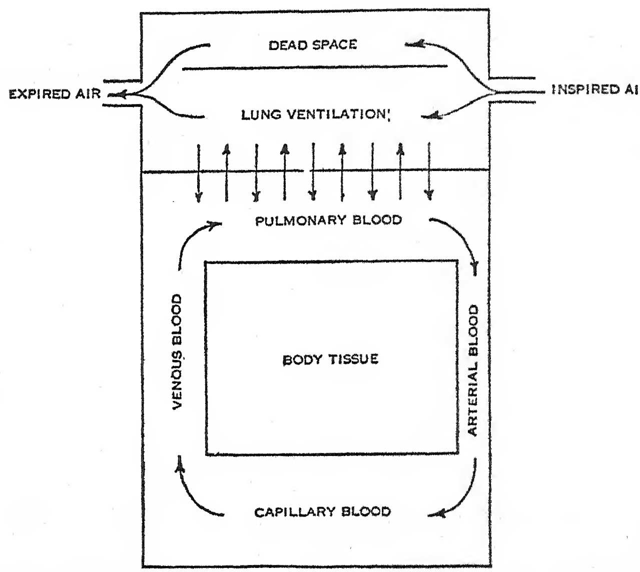


Figure 27. Diagram Showing Relations of Circulation, Body Tissue, and Air in the Lungs.

Arterial blood is distributed to all parts of the body. The working tissues have, as a result of their activities, a greater pressure of carbon dioxide, but a lower pressure of oxygen, than the blood. In passing through them oxygen leaves the blood, passing from the capillaries to the tissues, while carbon dioxide passes from the tissues into the blood. The blood leaving the capillaries contains more carbon dioxide but less oxygen than the arterial blood. This blood is collected in the veins and is pumped by the right side of the heart through the capillaries of the lungs for equilibration with the air in the lungs.

In Figure 27 the relations of the lungs, the circulating blood, and the tissues are illustrated, but in a much simplified diagram.

The compartment at the top represents the lungs. Instead of a vast

number of minute sacs opening to the air, the lungs are here figured as a single chamber. Moreover, the air is shown as entering at one side and emerging from the other, whereas in the body it is alternately drawn in and forced out through the same passageway. The central block in the figure represents the tissues of the body. The area surrounding the center represents the circulating blood. The layer of blood at the top is that flowing through the capillaries of the lungs. This blood exchanges gases with the air in the lungs; the exchange is indicated by arrows for carbon dioxide leaving and oxygen entering the blood. The layer of blood to the right of the tissues represents the stream in the arteries. No exchange of gases takes place through the arteries. The layer of blood below the tissues represents the stream through the capillaries. Here the blood exchanges gases with the tissues, oxygen leaving and carbon dioxide entering the blood. The venous blood is shown returning to the lungs to the left of the tissues. As in the case of the arteries, no exchange of gases takes place through the veins.

Adjustment of Breathing to Rate of Vital Combustion.

The volume of air breathed by a man resting or exercising is chiefly regulated not by the demand for oxygen, but by the production of carbon dioxide. The blood leaving the lungs contains under all ordinary circumstances more oxygen than the tissues draw for their needs. Carbon dioxide is added to the blood by the tissues in amounts determined by the activities of the tissues. It is by the varying amounts of carbon dioxide added to the blood that breathing is adjusted to the rate of vital combustion. The amount of air breathed in any period of time is that necessary to remove the excess of carbon dioxide from the venous blood coming to the lungs so as to maintain a uniform and rather high concentration of carbon dioxide in the arterial blood leaving the lungs.

Carbon dioxide dissolves in blood just as it does in water or any other fluid; the amount dissolved varies directly with the pressure of the gas in contact with the blood. But in addition, blood is capable of holding a much greater amount in loose chemical combination. Carbon dioxide is an acid substance when it is dissolved in water, for part of it reacts with the water, forming carbonic acid, H_2CO_3. The reaction is as follows:

$$CO_2 + H_2O \leftrightarrows H_2CO_3$$

This reaction is reversible. The amount of acid formed varies with the amount of carbon dioxide absorbed and hence with the partial pressure of carbon dioxide to which the fluid is exposed.

The blood contains inorganic alkaline substances and also proteins which can neutralize acids. The blood is capable of converting some of the sodium chloride which it contains into alkali by absorbing the chlorine into the red corpuscles. When carbonic acid enters the blood it combines with the alkali and is neutralized. Blood is slightly alkaline under all conditions, but its degree of alkalinity varies with the extent to which its available alkaline substances have been combined with the carbonic acid.

The amount of alkaline substances in the blood is constant under conditions of health and residence at any one altitude. Most of these alkaline substances come from the food eaten, and the uniformity of their amount in the blood is maintained by the selective secretory activity of the kidneys. If the diet contains more alkaline substances, from fruit and vegetables, than the blood requires, the excess is eliminated through the urine, which becomes alkaline; conversely, when an excess of acid substances, arising from the metabolism of protein (especially from its sulphur and phosphorus), enters the blood, it is secreted through the urine, which then becomes acid (see Chapter XI).

Since the alkaline substances in the blood are normally maintained in constant amount, the only variable affecting the alkalinity of the blood is the amount of carbon dioxide dissolved in it. When blood is exposed to carbon dioxide at a pressure greater than that of the carbon dioxide already in the blood, carbon dioxide enters and the alkalinity of the blood is diminished. If the blood is then exposed to air containing carbon dioxide at a pressure lower than that in the blood, carbon dioxide passes out into the air and the alkalinity of the blood is increased. The first of these conditions occurs in the tissues, the second in the lungs.

The activity of breathing is controlled by a nerve center in the brain. This center is sensitive to slight variations in the alkalinity of the arterial blood which reaches it. If the alkalinity is reduced below the normal value, breathing is increased, so that more carbon dioxide is removed from the blood passing through the lungs; contrariwise, if the alkalinity is increased above the normal value, breathing is reduced or stopped until sufficient carbon dioxide has accumulated in the blood to restore the normal alkalinity.

Volume of Air Breathed.

Blood has the normal degree of alkalinity only when it has been exposed to and brought into equilibrium with air containing an exact percentage (or pressure) of carbon dioxide. At sea level in healthy people this amount of carbon dioxide is 5.5 per cent of the pressure of one atmosphere. The air in the lungs to which the blood is exposed is so regulated that it contains constantly this amount of carbon dioxide. The volume of air breathed for any rate of production of carbon dioxide is the amount of air necessary to dilute this carbon dioxide to 5.5 per cent.

For a summary of these facts we may again refer to the diagram, Figure 27. The air in the compartment indicated as the lungs contains 5.5 per cent of carbon dioxide because the flow of air is adjusted to the amount of the gas coming to the lungs so as to maintain this amount. The arterial blood leaving the lungs has a degree of alkalinity corresponding to this percentage of carbon dioxide. This blood circulates to the tissues, where carbon dioxide is added to it. The blood with the added carbon dioxide circulates to the lungs. There it gives up some of its carbon dioxide to the air in the lungs. If the carbon dioxide in the air in the lungs is to be maintained at the normal level of 5.5 per cent, air must be brought in to dilute the carbon dioxide. The amount of air breathed into the lungs in any period is exactly the amount of air necessary to dilute the carbon dioxide brought to the lungs in that time down to 5.5 per cent; no less but no more.

On this basis the amount of air breathed per minute can be calculated for any rate of production of carbon dioxide. The tissues of a man at rest produce each minute between 200 and 300 cubic centimeters of carbon dioxide. For the first of these values a normal man will breathe so that 3.6 liters of air will be passed in and out of the lungs each minute; for the second, 5.4 liters. These two volumes are, respectively, the amounts of air necessary to dilute 200 and 300 cubic centimeters of carbon dioxide to a concentration of 5.5 per cent; that is, 200 cubic centimeters is 5.5 per cent of 3.6 liters, and 300 is 5.5 per cent of 5.4 liters. Under moderately vigorous exercise the tissues of the man produce approximately 1 liter of carbon dioxide each minute; by the same calculation the volume of air passed in and out of his lungs in this time would be 18 liters. In extreme exertion the amount of CO_2 produced each minute is between 3 and 4 liters; the corresponding volumes of air are 54 and 72 liters.

The volume of air passed in and out of the lungs and equilibrated

with the blood is not the same as that of the air breathed. Approximately one-third of the air inhaled does not reach the lungs; it merely fills the pharynx, windpipe, and bronchial tubes, the so-called respiratory dead space. During expiration this air is breathed out and is followed by the two-thirds of the previously inspired air which has reached the deeper portions of the lungs. In Figure 27 the dead space is illustrated as a partition dividing the compartment of the lungs. The air passing over this partition is in the dead space, that passing below is in the deeper parts of the lungs; only the latter takes part in the exchange of gases with the blood. Although the air in the lungs, equilibrated with the blood, contains uniformly 5.5 per cent of carbon dioxide, the expired air contains only some 3.5 per cent, thus showing a dilution of about one-third. The volume of air breathed by the man in the example given in the previous paragraph is greater by 50 per cent than the volumes given there as the air passed through his lungs. His actual volume of breathing per minute, with this allowance made for the dead space, would be between 5.4 and 8.1 liters at rest, instead of 3.6 and 5.4 liters; 27 liters for moderate exertion, instead of 18 liters; and between 81 and 108 liters for extreme exertion, instead of 54 to 72 liters.

Experiments Demonstrating the Control of Breathing.

Two simple experiments serve to demonstrate that the volume of air breathed is regulated by the carbon dioxide in the arterial blood: When the breath is held, carbon dioxide accumulates in the air in the lungs, for it is brought there continually by the venous blood. As the concentration rises a correspondingly greater amount remains in the arterial blood, for the blood is at every instant in equilibrium with the lung air. The alkalinity of the blood is momentarily diminished. As a result the demand for breathing becomes increasingly insistent until finally a breath must be taken. The length of time the breath can be held is determined by the rate of carbon dioxide production in the body and by the amount of alkaline substances which the blood contains.

During or immediately after muscular exertion the breath can be held for only a brief period, for the rapid production of carbon dioxide causes a correspondingly rapid increase in the carbon dioxide in the blood. When the blood alkali is reduced for any reason—for example, in some forms of disease of the kidneys—the time that the breath can be held is shortened. The average person at rest can, after taking a

single deep inspiration, hold his breath for a period of thirty seconds to one minute. If, now, instead of a single inspiration, a series of very deep inspirations and expirations, so-called "forced breathing," are made for one or two minutes and with the last inspiration the breath is held, it can be so held for a period of two to four minutes. To produce this result the forced breathing must be real; there is a tendency after the first few deep breaths to curtail the amount of air moved. The forced breathing brings to the lungs a greater volume of air than is required to dilute the carbon dioxide produced in the body during the time to the normal 5.5 per cent. The desire to breathe does not arise until the carbon dioxide has accumulated to the normal level. In holding the breath after prolonged forced breathing the blood is largely depleted of its oxygen before the carbon dioxide has accumulated to the point at which breathing is stimulated. Under such circumstances the oxygen deficiency assumes control of breathing. By doing forced breathing and with the last inhalation filling the lungs with oxygen, the breath can be held for six to eight minutes; the record is over thirteen minutes.

Acidosis and Alkalosis.

The degree of alkalinity of the arterial blood under normal circumstances is as constant as is the temperature of the body. Just as the temperature may be disturbed under certain circumstances, so also may the alkalinity of the blood. If the amount of carbon dioxide in the lungs and in the blood is high in proportion to the amount of alkaline substances, the blood is less than normally alkaline; this condition is called acidosis. In the reverse condition the carbon dioxide is low in proportion to the alkaline substances and the blood is more alkaline than normal; this condition is called alkalosis.

Alkalosis occurs when the volume of air breathed is increased out of proportion to the production of carbon dioxide. Thus in the experiment with forced breathing, described in the previous section, the excessive amount of air breathed dilutes the carbon dioxide in the lungs to a subnormal level and alkalosis develops. Alkalosis is accompanied by changes throughout the body; the blood pressure is diminished, there is dizziness, pain in the head, and, in severe alkalosis, even nausea and vomiting. The condition known as mountain sickness, to be described subsequently, is partly due to alkalosis. The diminished oxygen in the air at the high altitude results in overbreathing.

Acidosis occurs when the volume of air breathed is diminished out

of proportion to the production of carbon dioxide. In holding the breath without preliminary forced breathing carbon dioxide accumulates in the lungs and acidosis develops. During exercise there is a mild degree of acidosis, for the breathing does not, as a rule, fully keep up with the production of CO_2. Unlike alkalosis, acidosis does not produce unpleasant effects unless the condition is very severe. In acidosis there is an increasing desire to breathe, the blood pressure is elevated and the head may throb.

Acidosis is produced by some diseases as well as by the temporary conditions of holding the breath and by exercise. In certain diseases of the kidneys non-volatile acids are believed to accumulate in the blood and to combine with the blood alkali. These acids cannot be ventilated out of the blood in the lungs as can carbonic acid, and the amount of alkaline substances available for combination with carbonic acid, and to balance its acidity, is thus diminished. Normally the kidneys would rapidly remedy this condition by secreting an excess of non-volatile acids in the urine, but the diseased kidneys cannot do so. Persons so affected breathe excessively on slight exertion and can hold their breath only for a short time.

Many erroneous ideas have been promulgated in regard to acidosis by diet faddists. The blood under no circumstances becomes acid during life. In fact, the diet, unless it is extremely abnormal, has little influence upon the balance of acid and alkaline substances in the blood, for the kidneys regulate the alkali to its proper level. It is only when the kidneys fail in their function that the balance is disturbed, and the diet may then play an important part in maintaining the proper level of alkali. Even then the action of the substances in the foods liberating alkali and acid is indirect, and any special diet is intended primarily to spare the kidneys unnecessary work.

Many erroneous ideas have likewise been promulgated in regard to the occurrence of acidosis during infections such as head colds and vaguely defined conditions of ill feeling such as those following overeating or alcoholic intoxication. Alkaline remedies are suggested to correct the so-called "acid condition." Acidosis is not caused by such minor disturbances of health and, even if it were, it would not produce the symptoms attributed to it. Sometimes the term "acid condition" is understood to mean gastric hyperacidity rather than a decrease in the alkalinity of the blood. As pointed out previously (page 37), the assumed hyperacidity is usually a derangement in nervous control of the motility of the stomach and its valves.

Pressure of Atmospheric Gases.

The terms pressure and percentage of gas, as applied to the carbon dioxide and oxygen in the lungs, have been used together here, but they are not synonymous. The distinction is important for the discussion of disturbances arising from exposure to high and low atmospheric pressure.

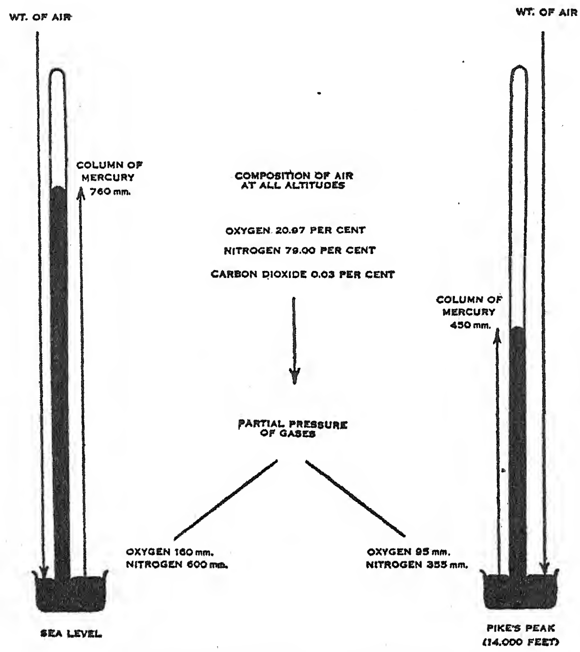


Figure 28. Partial Pressure of Gases.

The air above the earth is pressed down by its weight. The barometer is the instrument used to measure this pressure. At sea level the weight of the air above the earth supports a column of mercury in the barometer 760 millimeters high: 760 millimeters of mercury is equivalent to 15 pounds to the square inch. With higher or lower altitudes the barometer falls or rises in accord with the thickness of the layer of air. Thus at an altitude of 23,000 feet the barometer stands at only one-half its sea-level value. This is the height to which some of those who attempted to ascend Mt. Everest became more or less acclimatized.

If a mixture of gases is compressed, each gas within the mixture

exerts an individual or partial pressure equal to its fraction in the mixture. The sum of all the partial pressures equals the total pressure upon, and in, the mixture. Air is a mixture of (very nearly) 21 per cent oxygen with 79 per cent of nitrogen and other inert gases and a negligibly small amount of carbon dioxide (0.03 per cent). Since at sea level the pressure exerted upon, and by, the air is 760 millimeters, the partial pressure of the oxygen, in perfectly dry air, is 21 per cent of 760 millimeters, or 160 millimeters; and the partial pressure of the nitrogen (including other inert gases) is 79 per cent of 760 millimeters, or 600 millimeters. At an altitude of 14,000 feet, that of Pike's Peak, Colorado, where the barometer stands at 450 millimeters, the percentage of oxygen and nitrogen remains the same as at sea level; but as the total pressure is decreased, the partial pressures of the two gases are only 95 millimeters and 355 millimeters, respectively (95:355::21:79).

The amount of any gas dissolved in a fluid with which it is in contact varies with the partial pressure of that gas, but is otherwise independent of the percentage of the gas in the mixture. Thus twice as much oxygen dissolves in water exposed to air at sea level as dissolves in water exposed to air at 23,000 feet elevation, for the partial pressure of oxygen is there diminished to one-half its sea-level value. The amount of oxygen in combination with hemoglobin is also influenced by the pressure independently of other gases present. Thus at an altitude of 23,000 feet it would be necessary to breathe air containing twice the normal percentage of oxygen, and hence having the normal partial pressure, in order to bring the same amount of oxygen into the blood as at sea level. For this reason aviators who fly to high altitudes inhale oxygen. At a pressure of 160 millimeters an atmosphere of pure oxygen would have a pressure just equal to the partial pressure exerted by the oxygen at sea level and the blood would take up the corresponding amount of oxygen. Conversely, an atmosphere containing only 5¼ per cent of oxygen would be as good as normal air for a man working in a caisson under a pressure four times as great as that at sea level, 45 pounds gauge pressure.

Partial Pressure of Oxygen in Relation to Vital Combustion.

Oxygen is necessary to support life. When the blood fails to bring sufficient oxygen to the tissues to support their activities, unconsciousness results and death follows. The same is true of any type of combustion, such as that of a candle, but with the difference that the

candle is extinguished when the percentage of oxygen in the air is insufficient, while life depends not on the percentage but on the partial pressure of oxygen. Since the oxygen which reaches the tissues of a man must first be dissolved, its amount in the blood depends upon the partial pressure rather than upon the percentage of the gas in the mixture breathed. The behavior of a man and that of a candle flame are different in respect to a low percentage of oxygen and a low pressure of oxygen. A candle flame is extinguished when the oxygen in the air falls below 16 per cent. A man at sea level is not appreciably affected by this fall in oxygen, for the pressure at 16 per cent of an atmosphere is 122 millimeters, equivalent to the pressure of oxygen in the air at an altitude of 5500 feet (about the altitude of Denver, Colorado, or Mt. Washington, New Hampshire). Compression of the air to a thousand millimeters of mercury (about 4½ pounds gauge pressure) would restore the oxygen to a normal partial pressure, but still the candle would not burn, for the percentage of oxygen is not altered by the change in pressure. If the man and the candle were taken to high altitudes, the candle would burn quite well long after the man had collapsed, for although the pressure of oxygen is diminished, its percentage remains constant.

The man and the burning candle are also different in their reaction to a pressure or percentage of oxygen increased above that of sea level. The candle flame burns more brightly when the percentage of oxygen is increased above the normal 21 per cent; but increased pressure of air does not influence the flame. The combustion in the man is influenced by neither factor, popular superstition to the contrary. The hemoglobin of the blood is nearly saturated with oxygen at the ordinary pressure of oxygen in the air; increasing the pressure or percentage adds only an insignificant amount by simple solution. Moreover, the vital combustions are not regulated by the volume of air breathed, as an ordinary combustion in a stove is influenced by the draft, but instead, the body's energy expenditure determines the oxygen consumption.

Effects of High Atmospheric Pressure.

The effects of exposure to high atmospheric pressure illustrate the laws of solution of gases in fluids. Men are exposed to high atmospheric pressure in diving and in engineering work carried out under water in caissons and submarine tunnels. The highest pressures are

encountered in deep diving, and may reach ten atmospheres, 135 pounds gauge pressure.

The dress of the diver consists of a copper helmet which screws to a metal corselet over his shoulders, which is clamped water-tight to a stout suit of rubber covering the whole body except the hands, which project through elastic cuffs. Air is supplied to the diver through a hose attached to the helmet. Air escapes at the side of the helmet through a spring valve; this valve is adjusted by the diver to maintain the air within the helmet at a pressure slightly above that of the surrounding water.

For every thirty-two feet of fresh water or thirty-one feet of salt water, the pressure increases by one atmosphere, or nearly fifteen pounds to the square inch. It is absolutely necessary that the diver shall be continually supplied with compressed air so as to maintain the same pressure within his lungs as about his body. If the air pressure fails at a great depth, his breathing is stopped by the weight of the water against his abdomen and chest; blood is then squeezed up to his head in the inelastic helmet and pours from his nose and mouth, causing death.

A caisson is a chamber, sunk under water, with walls and roof but no floor, as the caisson rests on the bottom; it allows the men within it to excavate the dirt or rock and thus the caisson sinks. The top of the caisson is provided with air locks or chambers closed by two airtight doors. Compressed air is pumped into the caisson under sufficient pressure to force back the water which would otherwise enter the bottom. The workmen enter and leave the caisson through the air locks formed between the two doors. In tunneling operations under water the space back of an advancing shield is supplied with compressed air, and the entrance of water into the end is thus prevented. The railway and vehicular tunnels under the Hudson River were constructed in this manner.

Various physiological disturbances are associated with exposure to compressed air. As the pressure rises the first trouble usually noted is a sense of pain and pressure in the ears. This is due to an unbalanced pressure in the middle ears from failure of the Eustachian tubes, the passages from the throat to the middle ears, to open freely. The passages are liable to be blocked if the man has a head cold. They can usually be forced open and the pressure equalized by swallowing or by blowing with the mouth shut while the nose is clamped with the fingers. In men accustomed to compressed air the Eustachian tubes

open easily so that a diver can pass to a pressure of six or seven atmospheres in two or three minutes; but the uninitiated may have a long struggle with the Eustachian tubes before they can be comfortable in a pressure of even an extra half of an atmosphere; a rapid increase

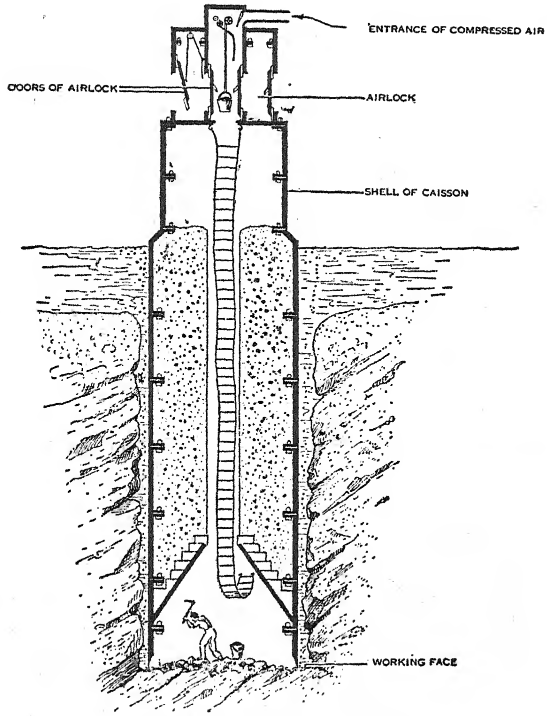


Figure 29. SCHEMA OF CAISSON.

The shell of the caisson is sunk in water and extends into an excavation made in the rock below the water. Water and mud are kept from entering the open end, where the men work, by the pressure of the air pumped into the shell. At the top of the caisson are airlocks shut off from the compressed air by doors. The men emerging from the caisson undergo decompression in these airlocks.

in pressure may result in the rupture of the head of the eardrum. The same difficulty with the ears may be met, though to a much less degree, in the rapid descent of an airplane, or even in descending a deep mine shaft, or in the elevator of a high building.

The chief dangers from working under compressed air do not arise, however, from the pressure of the air to which the men are exposed, but from the increased pressure of the gases in the air breathed. If

the air breathed is pure, the only gases which come into consideration are nitrogen and oxygen. If the air is rendered impure by breathing, as may be the case with a diver, carbon dioxide is also of importance. With a constant percentage of carbon dioxide in the partially vitiated air within the helmet, the partial pressure of the carbon dioxide rises in proportion to the pressure of the compressed air; and the physiological effect of the gas is dependent solely upon the partial pressure. Thus contamination of the air in the helmet with 2 per cent of carbon dioxide (18 mm. partial pressure) before descending into the water would produce no considerable effect, whereas the same percentage under five atmospheres would be equivalent to 10 per cent of carbon dioxide under ordinary pressure or 90 millimeters partial pressure, an amount which would incapacitate the man for any exertion. Thus both the volume of air supplied to the diver, and its pressure, are important. The ventilation must be increased in direct proportion to the depth and pressure at which the diver works.

Caisson Disease.

By far the most serious danger to men who work under compressed air is experienced not while they are "in the air," but after they have been decompressed to atmospheric pressure. In all work in compressed air it has been observed that soon after coming out some of the men become ill and some die or become paralyzed. The likelihood of these complications increases with the pressure and the duration of exposure. This form of illness is not experienced during the stay under pressure; it is only after decompression that the symptoms come on. In the worst cases the man collapses and in a few minutes is dead. In less serious cases his legs become paralyzed and he has what is known as diver's paralysis. In the slight cases, once very common among caisson and tunnel workers, there is severe pain in the limbs or in the body, known among the workmen as the "bends." The various symptoms which may develop after decompression are spoken of as caisson disease.

The cause of caisson disease lies in the high partial pressure of nitrogen to which those working in compressed air are exposed. Gaseous or elemental nitrogen is not utilized in the body. The gas is dissolved in all the fluids and tissues of the body at the partial pressure which exists in the surrounding air. The amount of nitrogen in solution remains constant so long as the pressure of the air is maintained uniform. When the pressure of the air is increased the body absorbs more nitro-

gen, for the amount going into solution in the blood passing through the lungs is proportional to the increase in pressure. From the blood the gas diffuses to all of the tissues, and they slowly become saturated with the gas at the partial pressure attained in the blood. The rate at which the gas can be absorbed is, however, limited to the rate at which it can enter the blood, and it takes many hours for the whole of the body to become saturated with nitrogen at a new pressure of this gas. The times required to reach full saturation for all pressures are approximately the same, but the total amount which will finally be absorbed in each case is proportional to the pressure. That is, it takes an equal length of time to become readjusted to the nitrogen at two atmospheres and at four atmospheres above the pressure of nitrogen in the air, but at the end the body will contain twice as much nitrogen in the latter case. The time of exposure, as well as the pressure, is therefore important in determining the amount of nitrogen absorbed. The greater the amount absorbed, other things being equal, the greater is the likelihood of caisson disease developing.

The absorption of nitrogen is not in itself detrimental, and no symptoms develop from it during the stay in compressed air. When the man returns to normal pressure, the excess of nitrogen which has been absorbed is eliminated through the lungs. Since the absorbed nitrogen can be eliminated from the tissues only by passage into the blood, its removal is slow. If the decompression is rapid the blood and tissues remain more or less supersaturated with nitrogen, and the gas may separate as bubbles. If these bubbles are formed in the blood they tend to block the circulation; if formed in and about the nerves, as is frequently the case, the tissue is injured and pain and paralysis follow. The opening of a bottle of soda water illustrates the separation of gas bubbles from a liquid in which gas has previously been held at a high pressure.

Caisson disease is treated by recompressing the man sufficiently to cause the separated nitrogen to redissolve in his blood and tissues. The ease with which this reabsorption can be effected depends upon the size of the bubbles which have separated; the smaller the bubbles, the more readily they redissolve. Therefore, the sooner the treatment is applied, the more likely is it to give relief. Recompression chambers or medical air locks are part of the equipment necessary for deep diving and caisson work. At the appearance of the first symptoms of the impending disease the man is placed in one of these large steel chambers which is at once sealed, and compressed air is admitted up

to approximately the pressure at which the man has been working. The pressure is afterward allowed to fall very slowly.

The prevention of caisson disease consists in decompression at such a rate as to prevent the formation of nitrogen bubbles in the blood. There are two methods by which this may be accomplished: continuous decompression and stage decompression. The first consists of a uniform diminution of the pressure, starting at that to which the man has been exposed and ending at atmospheric pressure. The time consumed in the drop of pressure depends upon the initial pressure and the length of exposure. In stage decompression the pressure is lowered not uniformly, but in steps. These steps are so regulated that the supersaturation of the nitrogen in the blood is kept below, but not too far below, the point of bubble formation. Men rarely, if ever, become fully saturated with nitrogen to the pressure of the air in which they have been working. Therefore, during the first part of the continuous decompression they are absorbing and not eliminating nitrogen, while during the second half the difference of pressure in their tissues and that in the air may be dangerously great. It has been observed that it is safe for men who have worked at a pressure of two atmospheres, 15 pounds gauge pressure, to pass immediately from this into normal pressure. With reasonable duration of exposure the same principle can be applied to any other pressures. Thus men who have worked in eight atmospheres can be dropped rapidly to four atmospheres without danger. After remaining at four atmospheres for a time the pressure is dropped by small steps until atmospheric pressure is reached. Caisson disease is much less likely to develop after such stage decompression than after continuous decompression.

Transportation of Oxygen in the Blood.

Oxygen is carried in the blood in loose chemical combination with hemoglobin. Some oxygen is also dissolved in the blood, but the amount is small, just as it would be in water. The arterial blood normally contains about one-fifth of its volume of oxygen; that is, each 100 cubic centimeters of arterial blood hold approximately twenty cubic centimeters of oxygen, or, as it is usually stated, 20 volumes per cent. Of these twenty cubic centimeters only 0.5 are in solution; the remainder is combined with the hemoglobin.

The reversible reaction between hemoglobin (symbol Hb) and oxygen is expressed by the equation:

$$Hb + O_2 \leftrightarrows HbO_2$$

When blood is exposed to atmospheric air the hemoglobin takes up oxygen and becomes oxyhemoglobin; when the blood is exposed to air or to tissues containing a less amount or pressure of oxygen, some of the oxygen passes from the blood and part of the oxyhemoglobin is reduced to hemoglobin. The reaction in the first direction occurs in the lungs, where the blood takes up oxygen; the reaction in the second direction occurs in the tissues, where the blood gives up oxygen. Thus the arterial blood contains more oxygen than the venous blood. This difference during rest amounts to from 3 to 5 cubic centimeters of oxygen for each 100 cubic centimeters of blood. During exercise the

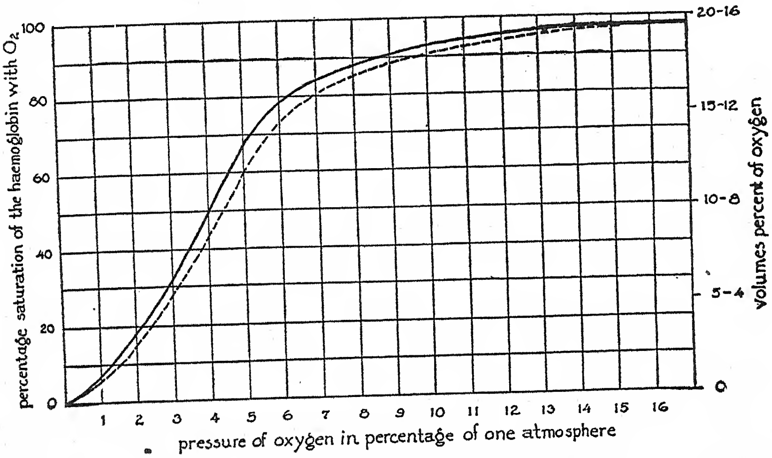


Figure 30. Oxyhemoglobin Dissociation Curve.
Solid line: in presence of 40 mm. carbon dioxide. Broken line: in the body.

difference increases and may amount to 10 or 12 cubic centimeters, depending upon the activity of the tissues and upon the rate of the circulation.

In the lungs the pressure of oxygen, in the percentage of an atmosphere, is about two-thirds of that in the outside air. This pressure of oxygen is sufficient ordinarily to convert nearly all of the hemoglobin into oxyhemoglobin; only a very little more oxygen could be carried by the blood if pure oxygen were breathed instead of air. When blood in a closed vessel is exposed to a pressure of oxygen below that in the lungs, oxygen comes off, at first less rapidly than the fall in pressure, so that at half the pressure in the lungs only about 10 per cent of the oxygen is withdrawn. Below this pressure the amount retained by the blood diminishes nearly in proportion to the decrease in pressure. The

amount of oxygen in the blood and the percentage of the hemoglobin in combination with oxygen, plotted against the pressure of oxygen to which the blood is exposed, give an S-shaped curve which rises rapidly and then gradually flattens. Such a curve is called the dissociation curve of oxyhemoglobin; it is illustrated in Figure 30.

Effects of Low Atmospheric Pressure.

The cells of the body cannot carry out their function unless they are continually supplied with an adequate amount of oxygen. Shortage of oxygen, known as anoxemia, is followed by disturbances in cellular activity which range in severity from mild derangement in muscular coordination and lack of mental concentration, to immediate death. Anoxemia develops when the pressure of oxygen in the atmosphere breathed is too low to saturate adequately the hemoglobin of the blood, i.e., as in airplane flights to unusually high altitudes. It may also develop from any other disturbance which interferes with the transportation or utilization of oxygen. Thus anoxemia develops when the respiratory passages are blocked, as in drowning or strangulation, or when the air sacs of the lungs are filled with secretions, as in pneumonia, or after injury from poisonous gases. Likewise anoxemia develops when breathing is depressed by poisoning from morphine, alcohol, ether and other drugs; an insufficient quantity of oxygen is then brought to the lungs. Anoxemia also results, even when sufficient oxygen reaches the lungs, if the blood cannot carry an adequate amount, as is the case in severe anemia and in carbon monoxide poisoning; a diminished volume of blood flow as in heart disease may also lead to anoxemia from failure of oxygen transportation. And finally anoxemia develops when the tissues are unable to utilize oxygen even though a sufficient quantity is brought to them; this condition occurs in poisoning from cyanides.

In addition to these many sources of general deprivation of oxygen, there may be also local anoxemia when the circulation to an organ is impaired following thrombosis or arteriosclerosis. The blood flow may also be shut off in an arm or leg by pressure from the outside as from the application of a tourniquet; prolonged anoxemia from such pressure may be followed by death of the tissue, gangrene, a point of considerable precautionary importance in first-aid work.

Most of the varieties of anoxemia listed here are discussed in appropriate sections of this book; the one dealt with here is that due to breathing air containing oxygen at low atmospheric pressure.

The oxygen in the air at sea level can be reduced to about 16 per cent before any effects of anoxemia are observed. There is thus a considerable margin of safety at this altitude. Sixteen per cent of oxygen at sea level corresponds to the normal oxygen pressure at an altitude of 5500 feet, that of Denver, Colorado, or Mt. Washington, New Hampshire.

With further decrease in the oxygen pressure the symptoms of anoxemia develop at a rate and to a degree depending upon the extent of oxygen deprivation, its rate of development and its duration. There is also considerable variation in the susceptibility of different individuals to low oxygen pressure. Some men are noticeably affected at altitudes of 6000 or 7000 feet, most at 12,000 to 15,000 feet, and a few not until 16,000 to 20,000 feet. With gradual reduction of oxygen pressure over a period of twenty to thirty minutes as in an airplane flight, usually little discomfort is experienced until a considerable altitude is reached, but the effects of anoxemia may nevertheless show in disturbances of muscular coordination and mental concentration. The emotions may also be disturbed so that there are outbursts of unreasonable irritability or crying. The effects of anoxemia in some respects resemble those following mild alcoholic intoxication. With more severe anoxemia from continued rise in altitude unconsciousness follows, often with no warning. All of these features of anoxemia are of great importance in the piloting of airplanes; insidious effects of anoxemia unperceived by the pilot have unquestionably been responsible for many airplane accidents.

Acclimatization to Altitude.

If the exposure to low oxygen pressure is of considerable duration, as in mountain climbing or in residence at a high altitude, i.e., 10,000 feet or over, the process of acclimatization comes into play. The first symptoms of this condition appear after six to ten hours in the high altitude; usually they take the form of mountain sickness.

At full acclimatization at any altitude breathing is normally controlled by the rate at which carbon dioxide is produced. When anoxemia develops in going to a higher altitude the control is for a time exercised through the oxygen deficiency in the blood. The character of the breathing is then different from the ordinary type. The volume of oxygen in the body is much less than the volume of carbon dioxide; the same change of volume in the two gases as from the fluctuation during breathing makes a greater percentage difference in the oxygen.

In consequence, breathing is uneven; it behaves like an engine with too delicate a governor. This type of breathing is called Cheyne-Stokes breathing; there are a few deep breaths followed by a pause, then a crescendo in the size of the breaths, culminating in deep breaths, after which there is a pause. The cycle is then repeated. The breathing assumes more nearly the normal character when acclimatization has been effected. Some people breathe in this way when asleep, as may also persons with heart disease, for at sea level they are as short of oxygen as a normal man on a mountain.

With continued residence in the high altitude the carbon dioxide production gradually reassumes control of breathing. This change is effected through a readjustment of the alkaline material in the blood. The volume of breathing induced by the shortage of oxygen is greater than that required to maintain the carbon dioxide in the lungs at the 5.5 per cent normal at sea level (see page 195). The concentration in the lungs is therefore diminished. This alteration in turn upsets in the blood the balance between the carbonic acid and the alkaline materials. In consequence the blood is rendered more than normally alkaline; a condition of alkalosis develops and with it the symptoms of mountain sickness. A brief alkalosis with symptoms similar to mountain sickness may be experienced by anyone, even at sea level, if forced breathing is carried out for a number of minutes. The alkalosis resulting from the overbreathing at high altitude is remedied by a gradual excretion of alkaline materials by the kidneys. A new level of alkali is thus established, corresponding to the reduced carbon dioxide in the lungs. The normal ratio of carbonic acid to alkali in the blood is thus reestablished; the normal alkalinity is reattained; and carbon dioxide production thus reassumes control of breathing. Under the new conditions established by this acclimatization a greater volume of air must be passed through the lungs to remove a given amount of carbon dioxide, than at sea level. Thus at the altitude of Denver, Colorado, the concentration of carbon dioxide in the lungs is normally 4.5 per cent, in contrast to the 5.5 per cent prevailing at sea level. The greater volume of breathing brings more oxygen to the lungs to combine with the hemoglobin and thus in part compensates for the lower pressure of oxygen in the air. People at high altitude breathe more air for a given exertion than they do at sea level. On going from a high altitude to a low altitude the conditions described are reversed; under the influence of the increased pressure of oxygen alkaline substances

accumulate in the blood and the percentage of carbon dioxide rises until it becomes normal to the new altitude.

The process of adjustment to a new altitude here described is slow; it takes days, or even weeks, for the change in the alkaline substances in the blood to reach completion and a new equilibrium.

In addition to the alteration described, the amount of hemoglobin in the blood is also increased and the blood is thus able to carry a greater amount of oxygen. Early during acclimatization the spleen discharges a greater number of corpuscles into the blood, and the volume of the blood itself may be slightly reduced, thus concentrating the corpuscles. Later over a period of weeks a greater number of red cells are produced by the bone marrow. In individuals acclimatized to an altitude of 10,000 feet the blood, usually but not invariably, contains about a million more red cells per cubic millimeter than at sea level.

Poisoning by Oxygen.

Oxygen at pressures considerably higher than those in the air at sea level is a poison, not only to man but to all forms of life. It is not, however, until the oxygen has reached a pressure of more than three atmospheres, equivalent to an air pressure of fifteen atmospheres, that the symptoms of the poisonous action of the gas are immediately noted. This high pressure is necessary to force into the blood sufficient oxygen to injure the tissues. The lungs directly in contact with the oxygen at full pressure are injured at much lower levels, particularly if the exposure is prolonged. Thus pneumonia may occur in divers who, through fouling of their lines, are sometimes forced to stay for long periods at great depths. On the other hand, inhalation of oxygen is sometimes used to treat anoxemia developing from pneumonia; to protect the lungs, the oxygen is administered only at a concentration of 40 to 50 per cent. The breathing of pure oxygen has no detrimental effect unless, as in treating pneumonia, the exposure is long, a day or more. There is no danger of oxygen poisoning in the use of rescue apparatus employed for a few hours at a time by firemen and miners. In such apparatus an artificial atmosphere is supplied from a tank of oxygen carried on the back.

CHAPTER IX

THE LUNGS AND THEIR DISEASES

Structure of the Lungs.

The lungs are composed of a great number of minute sacs, or saccules, which are the terminal dilatations of very small air tubes called bronchioles. Each saccule is divided by delicate partitions into many

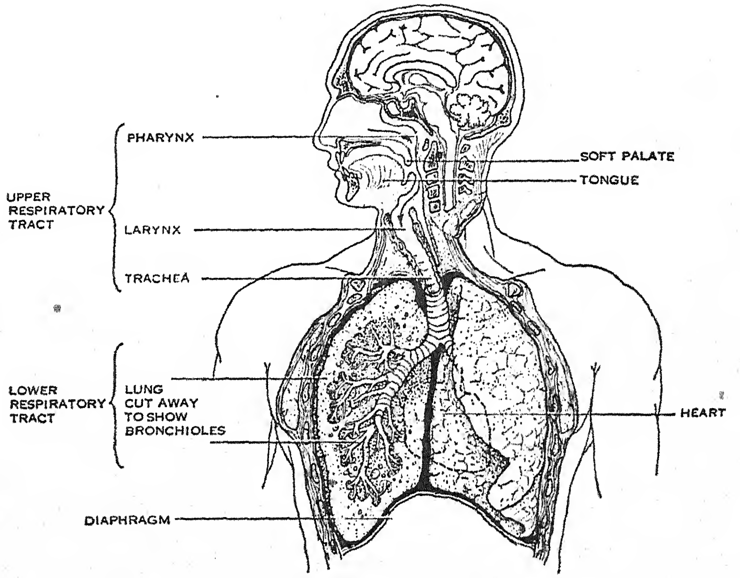


Figure 31. Respiratory Tract.

compartments, which are the ultimate air spaces, or alveoli. The bronchioles leading to the saccules are the branches of the bronchial tubes which spread out through the lungs. Fifty, a hundred, or even more of these bronchioles unite in a common tube, a bronchus. A bronchus with its bronchioles and air saccules is surrounded by a layer of connective tissue. The small mass thus inclosed, from which emerge only the bronchus and blood vessels running to the air sacs, is called a

lobule. A lobule with all its detailed structure is only about 0.5 centimeter in diameter.

The lungs are aggregations of lobules. The bronchi communicating with these lobules unite into tubes of increasing size; at the medial surface of the lungs and directly behind the heart these tubes open into the trachea, or windpipe. This tube, with its walls stiffened by incomplete rings of cartilage, extends upward and terminates in the pharynx, or throat. There is free access for atmospheric air to the lungs through the nose and mouth except momentarily when the glottis is closed during the act of swallowing or coughing. The smaller bronchial tubes are provided with muscular walls, and under irritation, or as the result of the disease asthma, may contract and prevent the passage of air into the saccules supplied by them. The trachea, bronchi, and bronchioles are lined with mucous membrane which secrets a mucous fluid upon its surface. The entire system of tubes takes very little part in the exchange of gases; it merely affords passage to and from the terminal air sacs.

Flow of Blood Through the Lungs.

The saccules and their alveoli have exceedingly thin walls; they are formed by a delicate elastic framework, almost completely filled with a network of capillary blood vessels and covered only by an extremely thin membrane. It is between the blood in these vessels and the air in the alveoli that gaseous exchange takes place. Because of the thinness of the walls and the enormous total surface of the capillaries (estimated at ninety square meters in the lungs of man), the process of diffusion of gases is so rapid that virtual equilibrium of partial pressure of every gas in the alveoli is almost instantly established between the blood in the capillaries and the air in the alveoli.

The blood is supplied to both lungs through arteries from the right heart. These are the only arteries in the body which carry the partially deoxygenated blood returned from the tissues. From their point of entry into the lungs the arteries follow the bronchi, dividing and subdividing until they form the capillaries of the alveoli. From the capillaries onward the blood vessels unite into increasingly larger vessels. These pulmonary veins finally emerge near the point of entrance of the arteries and pass to the left side of the heart. These are the only veins in the body which carry fully oxygenated blood. (See Figure 14.)

Cavity of the Chest.

Each lung has normally only one attachment in the body, which is that formed on the medial surface where the bronchi join the trachea and the blood vessels enter. At all other points the lungs are freely movable within the chest cavity. This cavity is bounded behind by the spine and muscles of the back, on the sides by the ribs, and in front by the ribs and breastbone. Muscles attaching to the edges of the ribs

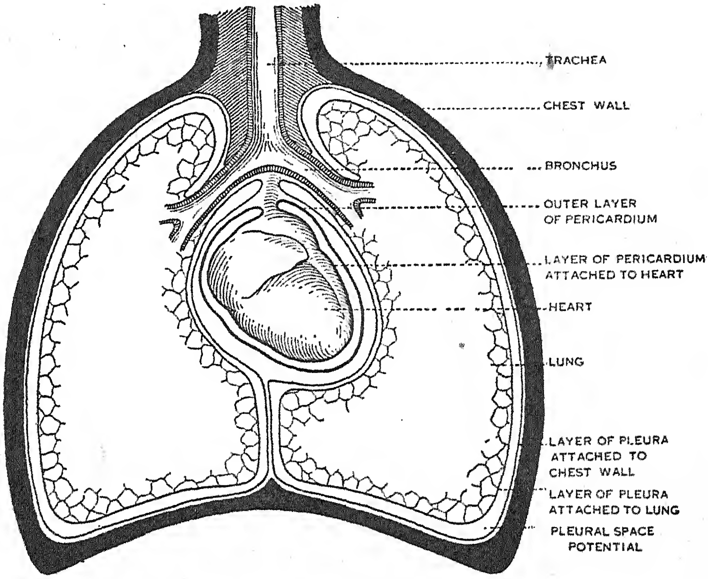


Figure 32. Schema of the Thorax.

Showing the relations of the parietal and visceral layers of the pleural sacs and the layers of the pericardium. The pleural space is potential; the two layers of the pleura are in contact and rub during the movements of breathing.

fill the spaces between these bones. The chest cavity is closed below by the diaphragm, which is a thin muscular sheet attached at its edges to the walls of the chest at the lower ribs. The upper surface of the diaphragm is convex.

The lungs are extremely elastic. In a lung which has been removed from the body the saccules contract until they are almost collapsed and contain only a small amount of air. In the body this collapse is prevented by the fact that the lungs are incased in the air-tight and comparatively rigid walled cavity of the chest. The lungs completely

fill this cavity; there is no air in the potential space between the walls of the chest and the lungs, and only a little fluid by which the walls are moistened sufficiently for lubrication. Since the interior of the lungs is in communication with the outside air through the trachea, the elasticity of the saccules is overcome by the pressure of the atmosphere, and the lungs are inflated and held tightly against the walls of the chest. By the same mechanism any movement of these walls, causing an increase or decrease of size in the cavity of the chest, results in a like change in the volume of the lungs, which are thus expanded or contracted in exact conformity to the size and shape of the chest cavity. As a result, air passes in and out of the air sacs and alveoli and through the trachea, thus producing the tidal movements of the air in and out of the nose and mouth.

The Pleura.

The surface of the lungs is covered by a thin layer of smooth tissue, the pleura. Similar tissue also lines the inner surface of the walls of the chest. The pleura resembles in appearance the peritoneum which lines the cavity of the abdomen and covers the intestines. The surface of the pleura covering the lungs and of that lining the chest are in contact, and slide over one another as the lungs expand and contract with the movements of the thorax.

Inflammation of the pleura is known as pleurisy. If the inflammation is dry, the roughened surfaces rub together during the movements of breathing, thus causing severe pain and a characteristic sound which can be heard by applying the ear to the chest wall. In other forms of infection the inflammation gives rise to fluid or pus which collects between the layers of the pleura and forces the lung away from the wall of the chest. The formation of pus under these circumstances is known as empyema.

Pleurisy results from the extension of an infection in the lungs. Thus it may be a complication of pneumonia; this is particularly true of empyema. Pleurisy with a clear fluid free from pus occurs more often in tuberculosis and rheumatic fever. The collected fluid is usually withdrawn by suction applied to a hollow needle passed through the chest wall; in empyema it may be necessary to make an opening by surgical operation and draw the pus through a tube. The inflamed surfaces of the pleura in contact with each other may grow together, forming adhesions.

Pneumothorax.

If an opening is made in the wall of the chest, air enters, the surfaces of the plura are separated, and the lung collapses. If the opening remains, the lung affected can no longer function, for the movements of the chest force air back and forth through the openings, instead of in and out through the windpipe. The layers of pleura which extend over the pericardial sac are attached to the back and front of the chest and to the diaphragm below, thus dividing the chest into lateral compartments. The partition, or mediastinum, thus formed is sufficiently strong to withstand the elastic pull of the lungs; accordingly, if the opening in the chest wall enters only one pleural space the lung on the other side is not seriously affected and continues to function. In treating tuberculosis it is sometimes desirable to rest the diseased lung by collapsing it; pneumothorax is then produced by admitting air about the lung through a slender hollow needle inserted between the ribs. Subsequently the air is gradually absorbed by the blood and the lung expands, coming back to its normal size in the course of a few weeks. To maintain the pneumothorax it is necessary to add air at intervals to replace that absorbed.

Movements of Breathing.

Changes in the volume of air in the lungs are brought about by movements of the diaphragm and ribs. Contraction of the diaphragm increases the length or height of the cavity of the chest, while an upward movement of the ribs, because of the direction in which they are hinged on the spine, increases the cross section of the chest, especially transversely. Inspiration is due to contraction of the diaphragm and of muscles attached to the ribs. These contractions are induced by nervous impulses. Expiration is a less active process than inspiration, for when the muscles relax the elasticity of the lungs themselves tends to drive out the air previously inhaled. This action is assisted by the twist or torque of the elastic ends of the ribs at their attachment to the breastbone, by the weight of the thorax in standing, and by the weight of the liver and other viscera upon the diaphragm when the individual is lying upon his back. Any impediment to breathing due to pressure or constriction in the respiratory passages is especially noticeable during expiration, because it is ordinarily of a passive character, a mere elastic recoil from the inspiration. When the volume of breathing is increased by physical exercise many accessory muscles are called into action to assist in producing deeper inspirations. Expiration

also involves, then, a vigorous action on the part of the abdominal muscles.

Volume of Air in the Lungs.

An adult of ordinary size, after making the deepest possible inspiration, can expire three to five liters of air; this is known as the vital capacity. The air moved at a single breath in normal breathing is known as the tidal air. Even in the most violent exertion it never reaches the vital capacity. The breathing during rest is from five to ten liters of air per minute; the number of breaths taken in the same time is between ten and twenty. The tidal air is thus approximately half a liter. During exertion both the rate and volume of breathing increase, but the rate less rapidly than the volume.

Only a fraction of the capacity of the lungs is called into play during quiet breathing. After an inspiration of the average depth it is still possible to draw into the lungs a considerable quantity of air; this volume is from 1.25 to 2.25 liters and is known as the complementary air. At the end of an average expiration a further volume of air can, with an effort, be breathed out. This is known as the supplementary air and its volume is approximately equal to that of the complementary air. In quiet breathing the tidal air occupies the mid-position in the range of the respiratory movements. If breathing is increased, as it is during and after muscular exertion, the greater tidal air encroaches first upon the complementary air. Although the movements of respiration are greater, the chest still comes to rest at the position occupied at the end of a normal expiration. With further increase in the volume of breathing the supplementary air is utilized and the muscles of active expiration are called into play. During very vigorous muscular activity most of the complementary and some of the supplementary air are used at each breath. The utilization of the complementary in preference to the supplementary air tends to maintain a larger volume of air constantly in the chest; it thus decreases the fluctuations in the concentrations of oxygen and carbon dioxide.

Even when the lungs are removed from the body they do not, in collapsing, force out all the air they contain; indeed, it cannot be pressed out. Before birth the lungs contain no air; after the first breath some of the air drawn in remains even though the infant dies immediately afterward. The presence or absence of air in the lung, usually determined by placing a piece of the lung in water to observe whether it floats or sinks, may thus be used in suspected infanticide to deter-

mine whether an infant was born alive or dead, that is, breathing or non-breathing.

Nervous Control of Breathing.

Unlike the heart, the muscles of breathing have no independent or automatic rhythm. They contract only in response to impulses which travel from the brain down the spinal cord and then by way of motor nerves to the muscles. These impulses arise and are coordinated in a specialized area in the brain, the respiratory center, which is in the medulla. The medulla is at the base of the brain and appears as a bulbous continuation of the spinal cord within the skull. The respiratory center has the function of adjusting the volume of air breathed so as to maintain a uniform alkalinity of the blood, the center effects the reciprocal alternation of inspiration and expiration.

The activity of the respiratory center is influenced by the slight variations in the alkalinity of the arterial blood arising from the variations in the production of carbon dioxide (see Chapter VIII). When the alkalinity is diminished the center sends out stronger and more frequent impulses; breathing is made deeper and more rapid; the volume of the tidal air is increased. The augmented volume of breathing tends to restore and maintain the alkalinity of the blood at its proper level. When the alkalinity is increased, the center ceases sending out impulses until the normal level of alkalinity is restored by the accumulation of carbon dioxide in the lungs and blood.

If undisturbed by influences which modify its action, the center sends out impulses in perfect rhythm; breathing is then regular, as it usually is in a sleeping man. On the other hand, in talking, singing, coughing, or sneezing, the normal rhythm is interrupted. Nevertheless, the respiratory center compensates for the interruption by a greater or less activity during the period immediately following. If the breath is held for a minute, there is breathed during the following minute or two an additional volume of air equal to that which would normally have been breathed during the time the breath was held. If the volume of breathing is voluntarily doubled for a minute, it is involuntarily decreased by an equal volume during the following minutes. The respiratory center is tolerant only to a limited extent toward these interferences with its action; if the breath is held until considerable carbon dioxide has accumulated, the center breaks away from voluntary control and the breath can no longer be held. For a similar reason it is impossible to sing or talk connectedly during or immediately after ex-

ertion. The increased carbon dioxide production then greatly shortens the time required for the carbon dioxide in the lungs to accumulate up to the level at which the center refuses to submit to voluntary control.

The movements of breathing are reciprocating—that is, back and forth like the movement of the piston of a steam engine. Such movements as walking, in which the legs are swung back and forth, and the wagging of a dog's tail, are also examples of reciprocating movements. The physiological mechanism of such movements always includes two antagonistic sets of muscles tending to move the part in opposite directions, as in inspiration and expiration. For the mechanism to act, it is necessary that one of the sets of muscles shall relax while the other contracts, and then that the first shall contract while the latter relaxes. The relaxation is as essential as the contraction, and the accurate timing of the alternation is essential for rhythm and efficiency. The rhythm and reciprocating action of breathing are usually involuntary. The rhythm continues automatically so long as any excitation flows into the respiratory center. Besides the nerves sending impulses to the muscles from the respiratory center, there are also nerves which carry impulses from the lungs to the center. The most important of these are the two vagus nerves, one in each side of the neck. When an inspiration has occurred and the lungs are stretched, the endings of the vagal nerves in the lungs are stimulated, as are also endings of nerves in the muscle of breathing, so that impulses are transmitted to the respiratory center. There they inhibit the inspiratory action and induce expiration. Conversely, the partial deflation of the lungs by expiration induces inspiration. The reversal of phase is carried out at the point which gives the proper volume of breathing as determined by the influence of the alkalinity of the blood upon the activity of the respiratory center.

Special Forms of Respiratory Movement.

In addition to breathing there are several special forms of respiratory movement, the most important of which are coughing, sneezing, laughing, crying, sobbing, yawning, and hiccoughing. Each of these acts is largely reflex and involves the exact coordination of several structures. Most of the movements are controlled by separate groups of nerve cells and connections in the brain near the respiratory center. When these special centers are aroused, they supersede the ordinary

action of the respiratory center, and initiate their characteristic form of respiratory movement.

Coughing.

Coughing tends to remove foreign substances from the respiratory passages. It is initiated by irritation of these passages, particularly the larynx. The irritation caused by a foreign body—phlegm, for example—sends an impulse to the cells controlling the coughing reflex. Impulses are radiated through the ordinary respiratory nerves to the muscles of breathing; a characteristic pattern of activity results, the act of coughing. There is first an inspiration, followed immediately by closing of the glottis, and then an effort at expiration so that the pressure of air within the lungs is greatly increased. The glottis is then suddenly opened, and the air rushes out with explosive force. Simultaneously, the air passage to the nose is closed off by the soft palate, so that any material which is driven out of the air passages passes through the mouth instead of the nose. The greatest velocity of the air is attained in the trachea and larger air passages. Consequently, coughing is most effective in removing sputum or foreign bodies from those regions. Even repeated coughing may fail to remove sputum from the more remote air passages, particularly if it plugs these passages and prevents the entrance of air during the inspiration which precedes each cough.

Coughing is a protective reaction, and its failure may be attended with a greatly increased danger of pulmonary infection. During anesthesia, deep alcoholic intoxication or unconsciousness from any other cause, the reflex is lost; and these conditions may be followed by aspiration pneumonia, that is, infection of the lungs caused by the passage of material down the trachea. In prolonged bronchitis, in advanced tuberculosis, and in the pneumonia of old and debilitated persons, the ineffective coughing results in a distinct increase in danger from the disease. When the upper respiratory passages are inflamed and there is little formation of phlegm, the continued coughing caused by the inflammation serves no purpose.

Coughing is, in some instances, attended with dangers of its own. It puts a strain on the tissue of the lungs, especially at the tips which extend above the collar bone. The resulting distention may be a contributing factor in the formation of a chronic dilatation known as "emphysema." The blood pressure is raised during coughing and

hemorrhages may occur in the brain or elsewhere from weakened arteries.

When coughing is undesirable, or when no sputum is raised by the cough as may be the case when the irritation initiating the reflex is in the throat, cough medicines are used. These are of three general kinds: (1) substances such as slippery elm, licorice, candy, and glycerin which, when dissolved in the mouth, form a soothing coating over the inflamed area of the throat; (2) substances which have a local anesthetic action and which when applied to the throat render it less sensitive; and (3) drugs such as codein and morphine which when taken internally lower the sensitivity of the cough center in the brain. Medicaments such as ipecac and ammonium chloride may also be added to cough medicines to increase the flow of mucus, "loosen the cough" and make it more productive.

Sneezing.

The act of sneezing is much like coughing; the soft palate, however, does not close off the passage into the nose, so that the outrushing air goes through both mouth and nose. Sneezing tends to remove substances which irritate the mucous membrane lining the nasal passages. The impulses which occasion the reflex act of sneezing originate in these passages and to a less extent in other organs such as the eyes; looking at a brilliant light may induce sneezing. The sneezing which follows exposure of the skin to chill or a draft arises only indirectly from the skin irritation. The chilling of the skin causes an alteration in the size of the blood vessels in the spongy tissue in the nasal passages; this change may excite the sneeze reflex.

Laughing and Crying.

Laughing is an act similar to coughing. The glottis is closed only lightly, however, and the comparatively weak expiratory blasts occur in a rapid series. The distinction between laughing and crying is largely in the accompanying facial expressions. Sighing consists of a deep inspiration followed by a prolonged expiration. Sobbing is distinguished from sighing only by the greater velocity of the inspiratory act, and it is usually accompanied by a spasmodic approximation of the vocal cords. Laughing, crying, and sobbing are the accompaniments of mental states, but they are, nevertheless, as much reflexes as is coughing. The origin of the stimuli for the act is in the brain instead of the respiratory passages. Moreover, coughing may also arise in the same

manner, either voluntarily or as a result of an unconscious imitation of others who have coughed in the same vicinity, as occurs in church or during dull lectures.

Yawning.

Yawning is a deep inspiration with the glottis wide open, and as a rule with the mouth also open; simultaneously, muscles of the arms and shoulders contract and stretch their antagonists. The significance of yawning is not understood; it has been suggested that it is due to a momentarily sluggish circulation in the brain. A yawn resembles the gasps occurring in asphyxiation.

Hiccoughing.

Hiccoughing is nearly the reverse of coughing. The diaphragm is suddenly contracted and at the same time the glottis closed on the air which is being rapidly inspired. The irritation which occasions the act may arise from inflammation of the abdominal organs, from irritation of the diaphragm as the result of swallowing hot food or drink, or from pressure in the stomach distended with food or gas. The condition is annoying, serves no apparent purpose, and is often difficult to control. The milder forms may sometimes be checked by coughing or sneezing, by swallowing ice, salt, vinegar, or cold water. Strongly pulling on the tongue at times gives immediate relief, and if this fails the attack may yield to the nausea caused by tickling the back of the throat. In rare instances hiccoughing, especially after surgical operation, may last for a week or longer and cause severe exhaustion. Inhalation of 5 to 10 per cent of carbon dioxide by stimulating breathing may overcome this condition.

Protection of the Lungs.

The temperature of the air breathed varies widely—more than 100° F.—so also its moisture content. The air generally contains solid particles such as dust and bacteria, and sometimes such vapors as sulphur dioxide from burning coal and various fumes from automobiles and factories. The membrane of the air sacs and alveoli of the lungs is delicate, and if anything except pure warm moist air is brought in contact with it serious damage results. The upper respiratory passages —the nose, throat, trachea, and larger bronchi—are less sensitive than the deeper structures. Irritation of the upper respiratory passages re-

sults at most in a sore throat, but irritation of the alveoli and air sacs leads to the much more serious pneumonia.

The upper respiratory passages protect the lungs by warming the air to body temperature, saturating it with moisture, and removing by contact the greater part of the solid particles and irritating fumes. This effective air conditioning takes place in a passage only about three inches in length. The average adult inspires some 500 cubic feet of air in twenty-four hours, enough air to fill a room eight feet in each dimension. Under ordinary atmospheric conditions the nasal passages supply to the air during this time more than a liter of water to moisten it and 70 or more calories to heat it.

The Nasal Passage.

The nasal passage consists of a rectangular chamber in the bones of the skull which affords a passage from the outside air into the pharynx. The hard palate which forms the roof of the mouth also forms the floor of the nasal passage. Above this passage are bones at the base of the skull. A central septum divides the passage longitudinally.

The forward end of the nasal passage is covered by the nose, which serves as a guard to the inner passage. From each side wall of the nasal passage three scroll-shaped bones project. These are the turbinate bones. They are surrounded by soft spongy tissue containing many blood vessels. The turbinate bones serve to increase the surface which is exposed to the air entering the nose.

The septum and turbinates divide the stream of air into thin layers which are brought into contact with the mucous membrane which lines the entire surface of the nasal passages. The mucous membrane is covered with cilia. Cilia are hair-like projections so minute as to be invisible without the aid of a microscope. These cilia wave back and forth continually, slowly in one direction and rapidly in the opposite direction. The mucous membrane contains many minute glands formed within the substance of single cells on the surface. These glands secrete continuously a tenacious fluid known as mucus. Mucus, aided by the action of the cilia, forms the air-conditioning medium of the nasal passages.

A continuous film of sticky mucus spreads over the entire surface of the mucous membrane. As the fluid evaporates to moisten the air, additional fluid as needed is supplied by the mucous glands. The layer of viscous, almost mucilaginous mucus blankets the cilia; the cilia in

turn move the layer of mucus slowly and steadily toward the throat and from there to the esophagus. Solid particles collected in the tenacious fluid are thus gradually carried back to the throat and so to the stomach. The nasal passages thus present to the air an unbroken moving layer of fluid highly adapted to the function not only of purifying and moistening the air but also of protecting the underlying mucous membrane. In addition to its other qualities, the mucus of the nasal passages contains an antiseptic, lysozyme, capable of dissolving most varieties of bacteria that occur in air. Tears likewise contain this antiseptic.

The advantages of thorough air conditioning are lost in breathing through the mouth. Likewise the normal continuity of the moving sheet of mucus may be interrupted by abnormalities in the structure of the nose, such as growths and deviations in the septum which interfere with the free passage of air. Any imperfections in conditioning the air that may follow are less important than the loss of protection to the mucous membrane normally covered by the mucus. Such disturbances may greatly increase susceptibility to infection. The use of sprays, oils, douches, or antiseptics in the nose, unless recommended by a physician for some special purpose, may likewise interfere with the action of the protective coating on the mucous membrane. Oils placed in the nose, especially of infants, may be inhaled into the lungs, causing irritation.

Erectile Tissues of the Nose.

The tissue about the turbinate bones is of peculiar structure; it is known as erectile tissue. The blood from the arteries, instead of passing into capillary vessels, runs into cavernous spaces which empty directly into veins. The pressure of the blood within these spaces is determined by the rate of flow through them. Ordinarily the pressure is slight and the spaces are flattened. When the arteries dilate, the spaces distend; an erection occurs. The degree of distention is also regulated by the tone or firmness of the muscular tissue in the walls of the spaces. Normally the blood flow may be increased without marked swelling of the tissue, for the tone of the walls of the spaces is also increased. The greater the flow of blood, the more heat is made available for warming and humidifying the air entering the nose. If, however, the arteries dilate and the walls of the space remain flabby, congestion results, and sufficient erection of the tissues occurs to cause a partial blocking of the nasal passages. This congestion is not

normal, for ordinarily such influences as cold air which increase the blood flow, also increase the tone of the walls of the vessels.

Congestion, together with actual swelling of the tissues, often occurs during local infections, such as the head cold. The breathing of cold air increases the tone of the vessels, and the congestion may be relieved on going out of doors; but it returns on coming back into the heated room. Vigorous blowing of the nose may compress the vessels and afford a brief period of relief from the obstruction; this occurs also in the act of sneezing. Certain drugs, notably ephedrin, when applied to the congested erectile tissue cause it to shrink, thus opening wider the nasal passages.

The Sinuses.

There are cavities in the bones of the forehead—the frontal sinuses; in the bones of the cheeks—the maxillary sinuses or antrums; and in the base of the skull—the sphenoid and ethmoid sinuses. The sinuses communicate with the nose through small passages which allow an equalization of the air pressure within the sinuses, just as the Eustachian tube does for the middle ear. The sinuses are lined with mucous membrane which is continuous with that of the nose. The film of viscous mucus covering the membrane of the more exposed passages likewise extends over surfaces of the sinuses; the mucus is continually secreted and continually moved out through the passageways leading into the nose.

The sinuses are less exposed, and therefore less readily infected, than are the nasal passages. Their mucous membrane is normally entirely free from bacteria. Nevertheless, the sinuses may at times become infected, usually as the extension of a head cold or other disease, particularly influenza, affecting the nasal passages. Sinusitis, inflammation of the sinuses, is often accompanied by pain, especially headache; the symptoms of a cold occurring at the same time are exaggerated and prolonged. The communicating channels to the nose may become closed from swelling, and the pus and mucus formed within the sinuses then collect under pressure, sometimes with serious consequences. Even when the communicating channels are open the mucopurulent material may be too gelatinous to flow out through the narrow openings. More often, especially in the antrum, it collects in considerable quantity before it drains out.

Any factor that tends to force material from the nasal passages into the sinuses predisposes to sinusitis. Of these the most important is

vigorous blowing of the nose, especially with the nostrils momentarily pinched shut. Incorrect blowing of the nose also predisposes to middle ear infection. Swimming, especially diving, in contaminated water,

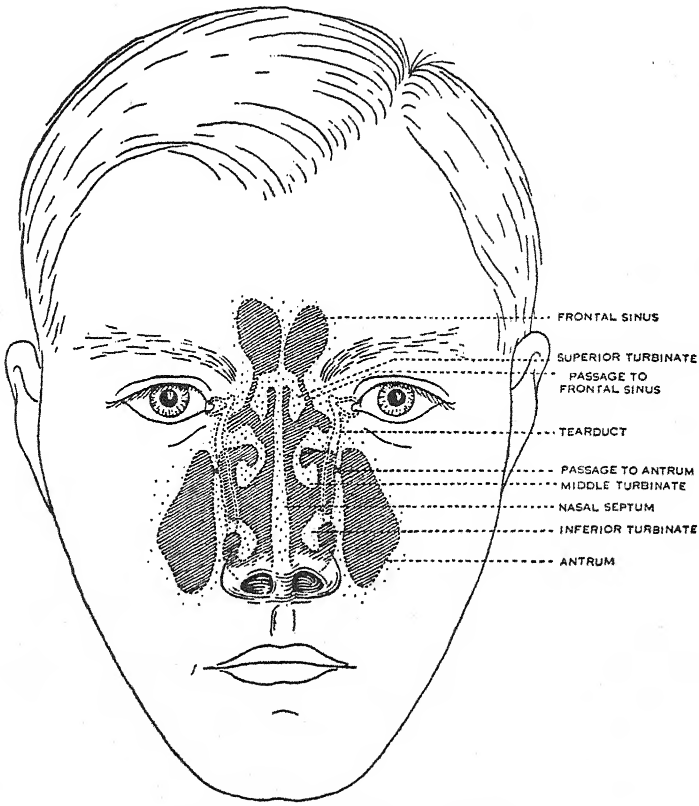


Figure 33. NASAL PASSAGE AND SINUSES.

The nasal passage is divided by the septum. The turbinate bones, covered with erectile tissue and mucous membrane, extend out from the lateral walls of the passage. The maxillary sinuses, or antrums, in the cheek bones, and the frontal sinuses in the bone of the forehead are lined with mucous membrane and are continuous with the nasal passage through small openings. The tear ducts also open into the nasal passage.

or at times even in pure water, may lead to infection of the sinuses. Fluid passing into the nose carries with it bacteria and secretions from the front part of the nasal passages and may wash them into the sinuses. In many instances infection of the maxillary sinuses results from decayed teeth. The tips of the roots of the upper teeth are close

to the floor of these sinuses; abscess of the teeth may extend to the sinuses.

In many instances acute sinus infections complicating head colds are unrecognized; their symptoms are mistakenly assumed to arise from an unusual severity of the colds. Sinus infections usually last longer than head colds, most cases extending from two to four weeks. When once infected, even if healed, the sinuses become more susceptible to subsequent infections. Attacks therefore are often recurrent; sometimes chronic infection develops. Abnormalities in the structure of the nasal passages which interfere with normal drainage of the sinuses predispose to both acute and chronic infections. The most suggestive indication of chronic infection is persistent nasal discharge, sometimes from only one side of the nose. This discharge may also drain to the back of the throat and be ignored as due to so-called chronic catarrh.

Nosebleed.

Hemorrhage from the nose is common, especially among children. In them, and in adults also, the bleeding usually occurs from the front portion of the nasal septum. Often the cause is not apparent. Injury may result from picking the nose to free it from crusts, or from blows on the nose. Hemorrhage through the nose may follow fracture of the skull. Nosebleed frequently occurs at the beginning of acute infectious diseases such as scarlet fever. In aged individuals bleeding that is difficult to control may result from the rupture of hardened arteries in the membranes of the nasal passages. The more common type of nosebleed can usually be controlled by gently forcing a wad of cotton into the nose (making certain that a portion is left projecting so that the plug can be removed easily) and compressing the nostrils against the cotton. If there is any possibility that the hemorrhage is the result of a fracture of the skull, no attempt should be made to stop the flow.

Infections of the Respiratory Tract.

The respiratory tract is subject to infections more frequently than any other part of the body. Respiratory infections stand third as a cause of deaths; they lead all other causes between the ages of fifteen and forty-five. The upper portions of the respiratory tract, the nose, throat, and trachea, are affected more often than the lower, the bronchi and lungs. The deeper the inflammation, the more serious are its consequences; coryza alone is never fatal, while pneumonia frequently is.

Inflammation of the deeper respiratory structures usually results from a downward extension of a comparatively harmless inflammation in the upper structures.

All of the respiratory passages, except the deepest structures of the lungs, are covered with mucous membrane; when inflamed this tissue becomes swollen and there is a profuse flow of mucus. Pus resulting from bacterial action mingles with the mucus, making it opaque and white or staining it yellow; the discharge is then said to be mucopurulent. Inflammation of mucous membrane is of the so-called catarrhal type, but the term catarrh, usually intended to indicate a chronic state of inflammation, has no proper medical meaning.

The Head Cold.

The word cold is medically an archaic term signifying a disorder resulting from inclement weather; in the past it was applied to any part of the body, as a cold in the intestines or a cold in the ear. The word has now largely lost this broad significance; the conditions once defined as "colds" are now known to be infections. In common usage the term, "head cold" or simply "cold," has been retained for the condition more correctly spoken of as coryza or acute catarrhal rhinitis.

Much misunderstanding in regard to the origin of head colds, and particularly their treatment, results from the common practice of calling every inflammation of the nasal passages, irrespective of cause, a head cold. The head cold is an acute infectious disease, spread from person to person just as is measles or any other similar disease. Unless complications result from an extension of the inflammation into the sinuses, the middle ear, or the trachea, the disease runs a course of about seven days followed by complete recovery. Inflammations of the nasal passages which are not infectious and are not truly head colds—but often so designated—may occur from many causes. Inhalation of smoke, dust, or fumes may irritate the mucous membrane and lead to congestion and discharge. These conditions are no more true head colds than sore throat from excessive smoking is an infectious tonsillitis. Non-infectious inflammations of the nasal passages usually clear up within a short time after the cause is removed; hence they may last only a few hours or a day or two. Often they are treated with home medication; the prompt recovery is attributed to the treatment which then may be strongly advocated as a reliable cure for colds. The multiplicity of remedies for head colds indicates the lack of any cure; it is

axiomatic in medicine that when any disease has many "cures" it really has none.

The infective material causing the head cold is capable of passing through a porcelain filter that will hold back all ordinary sorts of bacteria; it is invisible under the microscope. It is therefore believed to be either a virus (see page 546) or a bacterium of unusually small size. It is probable that this agent when brought in contact with the mucous membrane of the nose injures the membrane and diminishes its powers of resistance, i.e., affects the lysozyme. The membrane is thus rendered readily susceptible to infection from bacteria which often reach the nose but normally do not injure the mucous membrane. Many of the symptoms of the head cold, particularly the muco-purulent discharge, appear to be due to these so-called secondary invaders.

The infective agent of the head cold is present in the nasal secretions, not only those which flow from the nostrils but also those which pass into the throat and therefore reach the saliva. The head cold is transmitted by contact. This term is broad in its use, signifying not only direct contact but indirect as well. Droplets of secretion sprayed into the air during talking, sneezing, or coughing may float over a distance of several feet and be inhaled by anyone within this radius. This is contact infection, as is also the spread of the infective agent on dishes, glasses, silverware, handkerchiefs, and other articles of common use. Likewise handshaking, largely because of the habit of covering the mouth with the hand during coughing, may result in the transfer of the infection. It is difficult to prevent the spread of head colds in families, although it is highly desirable to do so if there are infants or ill or aged persons present. Prevention is best obtained by strict isolation of the affected person and sterilization of all articles used or touched. Crowding as in schools, workshops, theatres and street cars is highly conducive to the spread of head colds, especially if, as in some workshops, individuals face each other across work benches.

Opinion is divided as to whether certain unhygienic conditions, such as chilling the body, getting the feet wet, and occupying illy ventilated rooms, predispose to, or actually cause, head colds. Such is certainly not true in the case of other acute infectious diseases like measles or scarlet fever; their occurrence depends solely upon contact with someone who actually has these diseases. After they are acquired, however, they may be made much more severe by exposure and fatigue. In the still incomplete state of knowledge concerning the head cold the belief persists, and has received some experimental support, that the exposure

alters the condition of the mucous membrane of the nose to such an extent that inflammation follows. If this inflammation is a true head cold, then either head colds are not due to infection, or the infective agent is continually present. Neither of these possibilities appears tenable. Likewise the principle that exposure predisposes to colds is not supported in the case of fishermen and arctic explorers. Under conditions of severe exposure they are free from colds; they acquire them when they return to cities. The Eskimos are said to have no colds during the winter, but they acquire them when the trading vessels come to the north in the spring. It is probable that the belief that chilling causes head colds may in part arise from the fact that for some hours before the definite symptoms of a developing cold appear, the skin feels chilly, and drafts, not ordinarily noticed, are felt acutely. The chilly sensation, really a part of the cold, may be misinterpreted as the cause of the cold. Experimental transmission of head colds has shown the incubation period to be from one to four days—usually a longer time than that which elapses between the cold and the chill presumed to cause it.

Colds are least prevalent in June and July and most prevalent from September to November. This fact does not indicate any direct causative relation with the weather, for other infectious diseases in which exposure admittedly plays no part also have seasonal variations. Head colds occur in epidemics as do most infectious diseases, and in all parts of the world, but with greatest frequency in the temperate zone. In statistical studies of large groups in cities the average yearly occurrence of head colds ranges from one to three per individual. There are, however, wide individual differences, some individuals having as many as six colds a year and others none. It is improbable that a head cold confers immunity for more than a short period; experimental transmission in chimpanzees indicates an immunity of three to four months.

The incidence of colds is highest in children under five years of age; thereafter it decreases with age, although there is often a slight increase between the ages of twenty and thirty years.

The first symptom of a head cold is usually a burning sensation that seems to arise from a small area in the nose; this is followed by a feeling of dryness and discomfort throughout the entire nasal passages. Sneezing and increased flow of tears follow within a few hours; the nose becomes congested and obstructed; there is a profuse watery and irritating discharge. At this stage there may be headache, backache, general discomfort and sometimes slight fever. The mucous membrane

of the nose is red, swollen and tender. The discharge becomes mucopurulent. Usually about the third day the nasal obstruction begins to subside; if no complications develop the symptoms cease by the seventh day. The danger of the head cold lies in its complications; these consist in the extension of the inflammation into the sinuses, the middle ear, the larynx, the bronchial tubes, and even the lungs.

The treatment of the head cold should be designed primarily to prevent complications. Such prevention is best accomplished by rest in bed at least during the first three days of the cold and without exception during the presence of fever. All other treatment of head colds, except that at the hands of a physician, is directed toward relieving discomfort. It is advisable to use sprays, nose drops and nasal douches only under medical direction. Many measures contribute to the comfort of the patient; few to the cure of the cold.

Efforts to prevent head colds are nearly as unsatisfactory as treatment. Avoidance of those who have colds is the most logical measure and often the most difficult. The administration of vitamins A and D (also exposure to ultra-violet light) has been tried in the effort to build up a resistance to infection, but apparently their use is of benefit only when the diet is definitely deficient in these vitamins. The value of using vaccines administered either hypodermically or by mouth is uncertain; the vaccines contain only the organisms (killed) which are believed to be secondary invaders. They offer no protection from the virus which is believed to be the actual causative agent of the cold.

Laryngitis.

The larynx or voice box consists of a chamber of cartilage at the upper end of the trachea. All air breathed passes through it. The vocal cords are stretched across the larynx from front to back; when pulled taut by muscles the cords are vibrated when air is breathed in or out and sound is produced. The pitch of the sound is varied by tightening or relaxing the cords; the natural level of the pitch, as soprano or bass, is determined by the length of the cords. This length in turn is determined by the size of the larynx; after puberty the larynx of the male becomes larger than that of the female, with corresponding change in "voice." Except for the vocal cords the entire inner surface of the larynx is covered with mucous membrane continuous with that of the throat.

Inflammation of the larynx is known as laryngitis. It usually results from the downward extension of a head cold, but may also occur as

the result of excessive and improper use of the voice or the inhalation of dust, smoke, or irritant fumes. Swelling of the cords results in hoarseness; sometimes the voice is temporarily lost. In adults the condition is rarely serious, but in children the swelling may interfere seriously with breathing, giving the symptoms of one variety of croup.

Recurrent attacks of laryngitis may lead to chronic inflammation with persistent hoarseness. If hoarseness lasts for more than two weeks, thorough examination of the larynx by a physician is advisable. Persisting hoarseness may be a symptom of cancer of the larynx as well as of laryngitis. Cancer of this region is usually curable if detected early.

Bronchitis and Bronchopneumonia.

Bronchitis is an inflammation of the mucous membrane of the bronchial tubes. It is a common sequel to coryza and influenza and results from a downward extension of the infection. It often follows measles and whooping cough in children. Although the bronchitis is rarely serious in itself, it may lead to bronchopneumonia. The inflammation then extends into the finer bronchi, atria and alveoli of the lungs. Bronchopneumonia is not, for a vigorous adult, as serious a disease as lobar pneumonia, but in young children and old people it is often fatal.

Those who work largely indoors and at sedentary occupations are more liable to bronchitis than are persons who live an outdoor life. Exposure to excessive amounts of dust and to irritant gases or vapors predisposes to both bronchitis and bronchopneumonia.

In mild cases of bronchitis there is little fever, but in severe cases the temperature may rise to 100° or 102°. There is a racking cough with severe pain in the chest, particularly beneath the breastbone. In favorable cases the cough soon "loosens" and recovery follows after a week or ten days. If, instead of recovery, the bronchitis progresses to bronchopneumonia, the symptoms become more severe. The temperature may rise to 104° and there may be shortness of breath. When recovery occurs it is usually gradual and not by a sudden change following a crisis, as is the case with lobar pneumonia.

Bronchopneumonia is not the result of infection by a specific organism, a single type of bacterium peculiar to this disease; instead, it is caused by any type of bacteria which may infect the respiratory passages. Bronchopneumonia is not, in adults at least, a transmittible disease, for the organisms necessary for its development exist in any region of the upper respiratory passages that is infected, as during a head cold. It is primarily a complication, an extension, of such an in-

fection. The disease may, however, attack young children without any of the usual predisposing factors, but even with them it is more often a sequel to some other disease such as measles.

Lobar Pneumonia.

Lobar pneumonia is an infectious disease caused by a specific organism, the pneumococcus. Unlike bronchopneumonia, in which the inflammation travels downward to involve many small areas of the lungs, lobar pneumonia appears to start in the lung and involves the whole of a definite region, usually one or more lobes. The air sacs in the affected area become filled with coagulated serum and pus. The profound prostration of the disease results from the absorption of toxic products from the bacterial action in the lung tissue.

Lobar pneumonia usually commences abruptly with a severe chill, followed by pain in the side, cough, and an intense feeling of illness. The temperature rises to from 103° to 105°. Breathing is difficult. Delirium may occur. The disease continues usually with increasing severity for five to ten days. In non-fatal cases it ordinarily terminates abruptly by what is known as crisis. The serious symptoms cease abruptly, but the individual is left weak; convalescence is long and full strength is not regained for several months. In some cases the pneumococci spread in the blood, causing infections in many parts of the body, thus complicating the disease. The mortality from lobar pneumonia increases with age; it is about 10 per cent at twenty years, 30 per cent at forty, and almost invariably fatal after seventy.

Lobar pneumonia is an infectious disease, but its development appears to depend not only upon the spread of the pneumococci but also upon a susceptibility of the individual infected. This susceptibility has little to do with general health and vigor, for even the most robust may be affected; the disease occurs more often in men than in women. It is possible that the susceptibility is in the nature of an acquired tissue sensitivity to the pneumococcus; it is possible also that head colds and other infections of the upper respiratory tract may play a part in inducing this sensitivity. The majority of individuals acquiring pneumonia have had a cold or sore throat within two weeks prior to the onset of the disease.

Delicate serological tests have shown that there are many different types of pneumococci; more than thirty have been isolated. Three varieties known as types I, II, and III are responsible for about 70 per cent of all cases of pneumonia. The other varieties of pneumococci, collec-

tively designated as group IV, are responsible for the remaining 30 per cent. The feature of the organism which determines its type is not visible in structure but is chemical; it appears to be related to a peculiar substance of carbohydrate nature present in the pneumococcus. Immunizing sera have now been prepared for most types of pneumococcus infection. They are of benefit in treating the disease, but the type of organism causing the infection must be determined for each case in order that the correct variety of serum may be given.

Influenza or Grippe.

Unlike the head cold, with which its milder forms are often confused, influenza is not primarily a disease of the respiratory tract. It is an infection of the whole body, a general, not a local disease. Its most striking objective symptoms, however, come from the disturbances it causes in the respiratory tract; for this reason influenza is included among the diseases dealt with in this chapter.

The agent causing influenza has not been certainly identified; opinion differs as to whether it is a virus or a bacterium. There is, however, no uncertainty as to the way in which it is spread. During the disease the infective agent is present in the secretions from the mouth and nose; it is spread in precisely the same way as is the head cold—by contact. The incubation period of the disease is one to five days, usually two to three.

The peculiarity that serves to distinguish influenza from the head cold is, first, the nature of its onset, and, second, the severity of its general symptoms. The head cold commences with local symptoms, a burning sensation in the nose followed by a nasal discharge; fever and discomfort may develop later. In influenza the sequence is reversed; fever, a feeling of illness, and pain in the back and legs occur before the throat becomes sore or the nasal discharge appears. Within twenty-four hours after the onset, local and visible symptoms appear; the eyes water and are red; the throat is sore. In very mild cases the involvement of the respiratory tract does not extend beyond the throat. The temperature, which rises to 100° or 101°, subsides in two to five days. In more severe cases the symptoms of bronchitis appear, with coughing and the production of muco-purulent discharge.

The variety of mild influenza described here occurs in isolated cases or more frequently in small epidemics. It rarely leads to serious illness. Occasionally and for reasons not yet known, the disease increases in severity and spreads rapidly throughout the world. The occurrence of

such pandemics has been traced as far back as the twelfth century. In the nineteenth century severe epidemics occurred in 1833, and pandemics in 1847 and 1889; in the present century the first great pandemic was in 1918. In a few weeks in that year the disease caused more deaths than did the World War in its full duration.

Pandemic influenza is much more severe than the usual variety. The fever rises to 102° or 104°; bronchitis usually occurs, and frequently bronchopneumonia. The mortality results from the pneumonia. Even in the pandemics the actual death rate of the disease is low, averaging approximately 0.5 of one per cent, but an enormous number of people are affected so that the total number of deaths is high. In a pandemic as much as 40 per cent of the population may become ill within a period of six weeks. Forty per cent of a population of 100,000,000 is 40,000,000; a death rate of 0.5 of one per cent is, then, 200,000 deaths.

No other disease spreads over such wide areas in so short a time as does pandemic influenza. Its occurrence is independent of climate and season. Young and vigorous adults appear particularly susceptible to the disease. It is a highly dangerous one for women who are pregnant; most of them developing severe pneumonia.

No lasting immunity is conferred by an attack of influenza; the same person may have it several times. Some, however, are apparently not susceptible even to the pandemic variety, and most people are only moderately susceptible to the non-pandemic sort.

The spread of influenza is furthered by the close association of persons, particularly indoors. In theatres, churches, stores, schools and railway cars the conditions are conducive to the wide and rapid transmission of the disease. During the pandemic of 1918 the inmates of certain prisons, by reason of their isolation, remained entirely free from influenza. Strict isolation seems to be the only means offered for escaping the disease; and while it cannot be practiced for the public at large, it is advisable for pregnant women during severe epidemics and pandemics.

Tuberculosis.

Tuberculosis is the name given to the disease caused by infection with the tubercle bacillus. Although the disease is an ancient one, the bacillus which causes it was not discovered until 1882. The discoverer was Dr. Robert Koch of the University of Berlin. The name of the disease is derived from the nature of the change occurring in the tissues upon which the bacilli grow. There are produced nodules, or

small lumps, called tubercles, in which the bacilli are established. Ultimately the tubercles may be filled with a soft cheesy material, or they may ulcerate and produce open sores. If they heal, a scar is formed in which lime salts are sometimes deposited. In distinction to the inflammation caused by other local infections—a boil, for example—the growth of the tubercle bacillus produces no pus nor does it usually cause pain; a tubercular abscess is said to be "cold."

The bacilli may infect any organ or structure in the body. Thus there may be tuberculosis of the skin, called "lupus"; tuberculosis of the bones, which gives rise to such deformity as hunchback; tuberculosis of the lymph glands, especially in the neck, called "scrofula," which is more common in children than adults; and tuberculosis of such internal organs as the intestines, spleen, liver, or kidney. The most common seat of infection is the lungs, giving rise to pulmonary tuberculosis, sometimes called consumption, or phthisis.

Tuberculosis is not limited to man; it may affect other animals. Cold-blooded animals, and also cats, dogs, horses, and sheep, are seldom affected; but the disease is common in birds and particularly in cattle. There are minor differences between the bacilli which affect various animals. Man cannot acquire the disease from birds but may from cattle; children especially may be infected from the milk of diseased cows. Bovine tuberculosis transmitted through milk rarely induces pulmonary tuberculosis; it may be responsible, however, for tuberculosis in other organs, especially the lymph glands of the neck; the bacteria probably enter the body by way of the throat. Many cities now require by law that all milk sold shall either be pasteurized or supplied from cattle shown by periodic tests to be free from tuberculosis. Pasteurization consists in heating the milk, preferably after bottling, for a short time at a temperature a little below the boiling point. When properly performed, pasteurization destroys not only the organisms of tuberculosis, but also those of typhoid fever, scarlet fever, diphtheria, and foot-and-mouth disease.

Tuberculosis is strictly an infection; it can develop only as the result of the spread of tubercle bacilli. These organisms appear in the sputum of persons with the active form of the disease. They are transmitted by contact. Contact infection as described under the section on head colds implies the mingling of the sick and the well, but does not necessarily mean actual touch as in kissing. The transmission may be through objects of common use, such as pencils, water glasses, towels, or bed linen; it may also be through particles of sputum sprayed into

the air during coughing and inhaled by others. The tubercle bacillus is much more resistant to exposure than are the organisms causing head colds, influenza, and, indeed, most infections. Sunlight kills them in a short time, but they may live for weeks in rooms where sunlight does not penetrate. When sputum is discharged on to the floor of such places the bacilli become mixed with the dust and may be spread through the air. They may also be carried by flies.

Tubercle bacilli are not, as a rule, present in the nasal secretions or droplets of saliva, but only in the muco-purulent material raised by coughing. Therefore in ordinary circumstances of casual contact the spread of the bacilli is less active than that of the organisms of many epidemic diseases such as measles, influenza, or the head cold. A person with tuberculosis may largely control the spread of the disease by taking care to cover the mouth in coughing, to dispose of all sputum, to avoid soiling the fingers and to prevent others from using articles that have become contaminated.

There is little danger of acquiring tuberculosis from association with a person suffering from the disease, provided he has been educated to prevent the spread of the infection.

But before precautionary measures can be used, the presence of active tuberculosis must be recognized. This essential step is often a difficult one, for the disease usually shows at first no striking symptoms. It may be actively spread for months before the source of infection is recognized. In elderly people the disease may for years show no obvious symptoms except a cough which may be mistakenly attributed to "chronic" bronchitis.

Because of the peculiarities of its transmission tuberculosis is primarily a "family disease." The close and repeated contact most suitable to its spread is found in the home. In the majority of cases of tuberculosis developing in young people, the source of the infection is found to be some member of the family, or a household employee, such as a nurse, maid, or cook. Occasionally a school teacher may be the focus from which the bacilli are spread in the schoolroom.

The fact that tuberculosis often affects several members of a family (because of the contact there) has given rise to the erroneous belief that the disease is hereditary. Tuberculosis is not hereditary; the tubercle bacillus is not carried in either the ovum or the spermatozoon. The child of a tuberculous mother is born free from the disease, but the intimate contact between mother and infant, as in nursing, invariably results in the child acquiring the infection unless it is sep-

arated from the mother immediately after birth. Although acknowledging that tuberculosis is not hereditary, some sanitarians advance the idea that there is an hereditary predisposition to the disease. Such a tendency may or may not exist; in any event, it is of little importance. Even with the highest susceptibility the disease cannot be acquired without infection; and even the greatest resistance does not prevent the development of the disease if the infection occurs. The crucial point in the control of tuberculosis is the prevention of the spread of tubercle bacilli; all other features are secondary.

Human flesh is normally highly resistant to the growth of tubercle bacilli. Active and serious tuberculosis develops only when this natural resistance is overcome. The primary feature in breaking down this resistance is not, as is commonly supposed, an unhygienic mode of living, but instead a change within the body tissues brought about by the presence of the tubercle bacilli. The reaction of the body to tubercle bacilli received by infection for the first time is different from that occurring with subsequent infections. First-infection tuberculosis is in itself a harmless disease; reinfection may result in the serious form of tuberculosis such as consumption.

When tubercle bacilli for the first time reach the throat or lungs—or any other tissue of the body—they cause no local inflammation. The tissue does not respond acutely to their presence. The bacilli are carried to the lymph glands, such as those of the neck, or more commonly those of the lungs, clustering about the large bronchial tubes. In the lymph glands the bacilli set up a mild inflammation. Small tubercles are formed, but these are surrounded by scar tissue and often infiltrated with calcium. The development of the bacilli and the spread of the infection are stopped. The disease is limited entirely to the areas enclosed within the lymph glands. No ill effects are observed from this type of infection. Those affected do not have tubercle bacilli in their sputum; they do not spread the disease.

The natural resistance of the body is capable of arresting the bacilli in the glands, but it is not capable of killing them promptly. It is in this feature that tubercular infection differs from other infections. The bacilli persist, and although they cause no local harm their presence renders the body allergic—that is, sensitive—to the protein of the tubercle bacilli. Thereafter when bacilli come in contact with a tissue by infection the response is different from that to first infection.

After sensitivity to the tubercle bacilli is acquired, the bacilli that reach the lungs by infection are not immediately carried to the lymph

glands for disposal. Instead they cause inflammation on the surface of the tissue at the point where they are received. This inflammation holds the bacilli; tubercles are formed at the points where they touch the tissue. The tubercles occur, therefore, not in small collections in the lymph glands but in the open air sacs of the lungs, involving sometimes small and sometimes large areas of the lungs. The disease thus produced is the adult form of tuberculosis or chronic consumption.

The first infection gives rise to none of the symptoms of consumption; ordinarily it cannot be detected by physical examination unless an X-ray picture of the chest is taken; even then it may not be discovered. It can, however, invariably be disclosed by the so-called tuberculin test. This test, when positive, indicates the allergic condition developed in the body. In making the test a small amount of fluid obtained from a suspension of dead tubercle bacilli—hence containing the protein from the organism—is injected into the skin. If no infection has taken place, and hence no allergic state has developed, the skin about the point of the injection remains unchanged; the test is negative. If, on the contrary, infection has taken place, the skin shows, some hours later, the exaggerated response as a red area; the test is then positive.

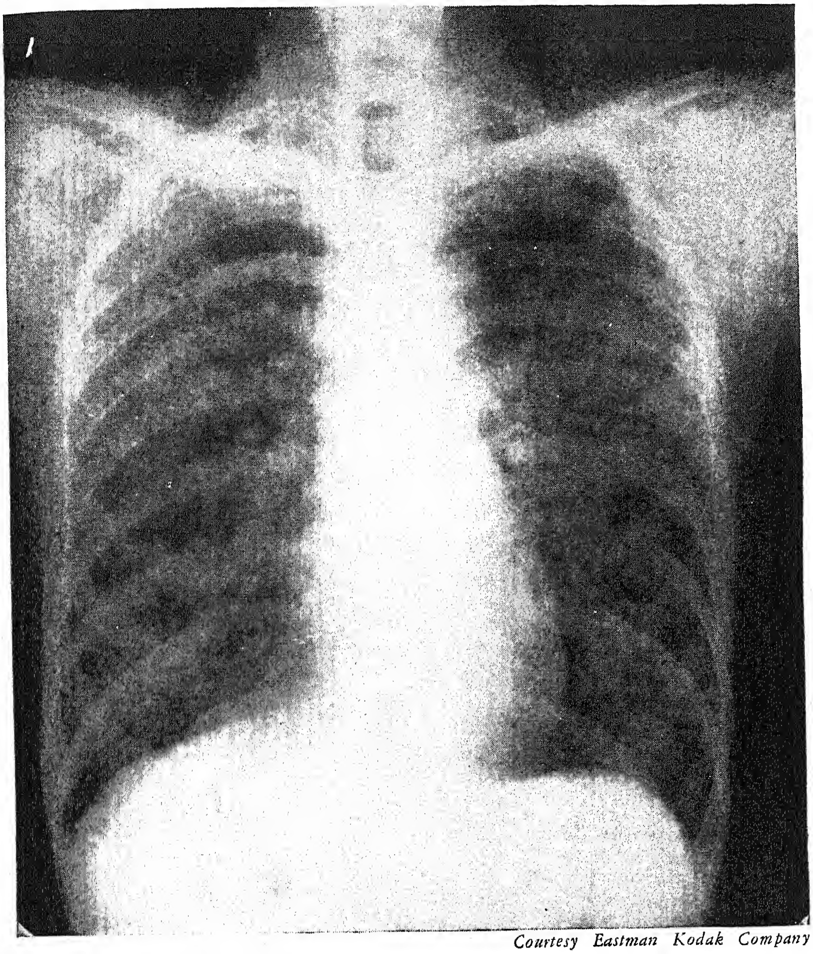
The serious forms of tuberculosis develop only in individuals who give a positive test for first infection. It does not follow, however, that all who show this reaction will develop consumption; only a small proportion do. A second infection must occur before the disease can develop. Occasionally this infection occurs from the escape of bacilli which have been held in the tubercles of the original infection. The organisms spread in the blood, giving rise to a rapidly developing form of tuberculosis; it may involve the whole of both lungs or the covering of the brain—tuberculous meningitis—or, in fact, any part of the body, or several parts at once. Such is not the usual occurrence in the development of the disease; ordinarily the second infection, or, indeed, many infections are received from the outside in the same manner as the first. The consequent effects depend in great measure on the extent of this reinfection. If it is slight the few tubercles formed tend to heal and scar over as do those in the lymph glands in first infections. The condition does not ordinarily progress to so-called active tuberculosis. If, however, the infection is large and often repeated as it is in prolonged intimate contact with a person with active tuberculosis, many tubercles are formed and the disease obtains a firm foothold in the body.

The development of consumption is ordinarily slow and insidious; it is not marked by any definite symptoms that point unmistakably to this condition. When the disease finally becomes clearly evident it is far advanced. Those with early and unrecognized tuberculosis discharge the bacilli in their sputum; it is they, rather than those who have the advanced disease and are under medical care, who form the centers from which the disease is spread.

The symptoms of pulmonary tuberculosis result from the absorption of poisonous products from the infected area and from the damage done to the lungs. There is nothing peculiar to the poisoning that marks it as unmistakably due to tuberculosis. It may at first consist of a sensation of tiredness, a disinclination to any exertion and the feeling that sleep is no longer refreshing. As the intoxication becomes more severe, fever develops. At first the rise of temperature is not marked, appearing only after exertion; later it tends to occur without the exciting cause, especially in the afternoon; its drop at night is often accompanied by profuse perspiration—night sweats. As the disease progresses there is loss of weight. It is this emaciation which gives the disease the name consumption. The fever of early tuberculosis often brings a sharply defined spot of color over the cheekbone. This hectic flush, together with the otherwise pale skin, moist and dilated eyes, the delicate slender form and languid manner, gives a certain appealing beauty to young women with incipient tuberculosis. Artists have painted and poets have written of this evasive beauty. But within a short time, possibly hastened by the responsibilities of marriage, the young woman becomes an emaciated invalid. In fact, in both sexes marriage hastens death from tuberculosis.

As a rule there is no pain in the diseased lung although masses of degenerating tubercles may lead to the formation of large cavities. Coughing appears as one of the early symptoms of the damage in the lungs, and is present in the majority of cases from beginning to end. At first the cough is dry and hacking, but subsequently it becomes looser and is associated with a yellowish expectoration. At times this expectoration may be bloodstained or blood itself may be expectorated. Hemorrhage of this type sometimes occurs in apparently healthy persons and may be the first indication of consumption.

Persons with advanced consumption have a decreased capacity for work and are easily fatigued. They are often irritable, intolerant, and petulant, but are usually optimistic as to their future health. Unless



Courtesy Eastman Kodak Company

PLATE IV. Radiograph showing advanced tuberculosis of the lungs. See page 240. The light gray spots that mottle the lungs indicate tubercles.

the disease is checked, the strength gradually fails until death results or a hemorrhage cuts short the "decline."

Although tuberculosis cannot occur without infection, the course of the disease is greatly influenced by the conditions under which the individual lives. Strain, exertion and malnutrition greatly expedite its progress. The occurrence of tuberculosis among adolescent girls increases when fashion decrees a slim figure, to be obtained by many only by partial starvation. Exposure to dust, especially silica, in industry greatly hastens the development of tuberculosis. Likewise, ill health from any debilitating disease, such as influenza, is followed by an increase in the activity of the infection. Many cases of tuberculosis first become recognizable following an upper respiratory infection—a cold or bronchitis that does not "get well."

Rest under good hygienic conditions is the main feature in the treatment of tuberculosis. If such rest is started early in the disease, recovery usually occurs without permanent impairment of health. Under such conditions the disease is arrested; a wall of scar tissue is formed about the diseased area, separating it from the rest of the lungs. This walling off of the infected portion is the healing process in tuberculosis; the disease, however, is not cured. It merely becomes latent. The bacilli may be retained for years in these "healed" areas and under suitable conditions may reestablish the disease.

Rest in bed, however beneficial an effect it may exert in retarding the disease, does not rest the lung itself since breathing must go on continually. If the disease is largely limited to one lung it is possible to rest the lung itself by collapsing it with pneumothorax. Recovery from the disease is often greatly hastened by this procedure.

The death rate from tuberculosis has decreased greatly in the United States, particularly in the present century. One hundred years ago tuberculosis lead by far all other causes of death; this leadership continued until 1910; in the following twenty years the disease declined to seventh place. One hundred years ago the death rate from tuberculosis was some 400 per 100,000 persons in the population; in 1885 it had fallen to only 350; in 1900 it was 202; in 1915, 146; and in 1930, 71. The decrease is due in part to the improvements in the standards of living and the general well-being of the community, and in part to the intensive organized effort to stamp out the disease by preventing the spread of infection. In spite of the gratifying decrease in the death rate from tuberculosis, this disease still remains the leading cause of death between the ages of fifteen and forty, the most productive pe-

riod of life. The prevalence of tuberculosis, more than that of any other disease, is an index of the standard of living in a country or in a community. In New York City the death rate from tuberculosis in the so-called slum district is ten to twenty times as high per unit of population as in the better residential sections of the city.

The eradication of tuberculosis demands the discovery and education and treatment of every individual affected with the disease. A consumptive uneducated in the disposal of his sputum, who coughs with mouth unprotected, or who in any way allows the dissemination of infectious material, is a menace to society. Unfortunately, many consumptives are ignorant of their disease until it has reached the point of disability; in their ignorance they spread the disease to their families and associates. The discovery of tuberculosis in its earliest stages is important, not only for the protection of society, but also for the individual affected. In its early stages the disease can be quickly arrested and serious illness prevented; in its advanced stages invalidism or death results.

The school, factory and office afford the best localities for making the tests necessary to trace down the sources of infection. The tuberculin test applied to all is the simplest means for selecting from the groups those who have been infected. X-ray examination of the chest of these individuals indicates whether their infection is of the childhood or adult type. Those with the adult type should receive prompt medical attention to arrest the disease, and education to prevent the spread of the infection. Those who show the arrested form of tuberculosis should be examined by X-ray at least once a year to discover the first indication of advancement in their infection.

The control of tuberculosis by preventing the spread of infection does not end in the discovery in the school, factory or office, of those infected; this is only the starting point. Each infected person, regardless of type of infection, has received the bacilli from an active case of tuberculosis; each one with the adult type of the disease may have spread it to members of his family. The next step is therefore to find the sources and to find the recipients. The test procedure and examination are carried into the home and applied to every member of the family of those who, in the school, factory and office groups give positive tuberculin tests. It is only by an organized attack along the lines indicated here that tuberculosis can be eradicated.

CHAPTER X

GASES, DUSTS AND POISONS

IN MODERN INDUSTRY, AND EVEN IN EVERYDAY LIFE, NOXIOUS GASES AND vapors are liberated into the air in increasing quantities. The inhalation of such substances to some extent is today almost universal. Fortunately, not all of these substances are extremely injurious, but comparatively few are entirely free from ill effect. The inhalation of many of these substances in sufficient quantity is deleterious to health and may even cause death. The nature of the consequences depends upon the kind of gas or vapor, and upon the length of time and the concentration in which it is breathed.

In contrast to the noxious gases and vapors, dust is a normal and important constituent of the atmosphere; all air breathed contains some dust. The normal dust of the atmosphere serves to limit the humidity of the air by precipitating moisture as rain. Without dust there would be no rain, clouds or mist. Instead, the moisture of the humid air would condense as dew on all surfaces with which it came in contact. What may be spoken of as the "normal" dust consists of mineral matter from the soil, volcanic ash, carbon, interplanetary particles, and salt from sea spray. Organic materials are also present in dust, although to a limited extent, and consist of dry particles blown into the air from disintegrating animal and vegetable matter, seeds, scales of the skin, pollen, fragments of hair, yeast molds, spores and bacteria. There is more dust in the air of cities than in the country, and usually more in houses than in the outside air.

Aside from the allergic reaction, such as hay fever, caused in susceptible individuals by organic dusts, ordinary amounts of naturally occurring dusts are not injurious. The dust is very largely separated from the air by the upper respiratory tract and does not reach the lungs; the small amount that does reach them is not usually of a nature to cause irritation. The amount of dust that the nose is called upon to remove from the air, even under the most favorable conditions, is large. The ordinary air of a city may contain 2,000,000 particles per cubic foot; 500 cubic feet of this air passes through the nose in twenty-four

hours. In certain dusty industrial occupations the air may contain as many as 2,000,000,000 dust particles per cubic foot. In some occupations the dust is of an extremely injurious character, causing either serious irritation of the lungs or poisoning from absorption.

Normal quiet breathing may not carry any dust into the deeper respiratory passages unless the amount in the air is unusually high or the dust exceptionally fine, as may be the case with silica dust. The heavy breathing during exertion and breathing through the mouth interfere with the normal removal of dust. If the dust is poisonous, as is that of arsenic or lead, the removal in the nose does not prevent poisoning; the dust stopped in the respiratory passage is swallowed.

Poisoning versus Irritation.

A poison, as defined here, is a chemical substance which has a harmful action after it is absorbed into the body. Although poison is commonly thought of as entering the body through the alimentary tract, that is, swallowed, there are other equally effective means of entry. Thus the poison may be injected into the flesh, from which it is absorbed into the blood, or it may be injected directly into the blood, i.e., intravenously. It may also be placed in the rectum and absorbed from there. And finally, of special importance here, it may reach the body in the air as a dust or vapor. Intoxication follows the drinking of alcohol; it can be produced as readily by rectal, hypodermic, or intravenous injection; it likewise results from the inhalation of air containing alcohol vapor. In poisoning, the manner of entry is determined by the physical nature and occurrence of the poisonous substance; the effects on the body are the same irrespective of the manner in which it is introduced.

Many chemical substances injure the surface of the body, the skin or the mucous membrane of the respiratory and alimentary tracts when brought in contact with it. Such substances are corrosive; they are called irritants. If the damage they do is limited to the surface, that is, if they are not absorbed, they are not, by the definition given here, poisons. Many poisons which cause death when absorbed in even minute amounts may be put on the skin with impunity. Such is the case with strychnine or morphine. On the other hand, many irritants which cause extensive damage to the surface are not absorbed into the body. Thus lime dust injures the mucous membrane of the upper respiratory tract, silica dust the lungs, and chlorine gas affects both. These substances or their products on the flesh do not cause poisoning.

There are, however, certain chemicals which are both irritating and poisonous.

Injury to the surface, the skin, respiratory tract, conjunctiva of the eye, and even the alimentary tract is followed by inflammation. The initial injury from the irritant may not result in visible destruction; the ill effects result from the subsequent inflammation. Thus in sunburn caused by the actinic light of the sun there are no immediate effects as in burning with a flame or hot iron. Inflammation develops later, and what we term "sunburn" is due to this inflammation. Inflammation is a reaction only of living tissue; it is impossible to produce sunburn in a corpse.

Classification of Noxious Gases.

Noxious gases (including vapors) may be classified according to their action on the body into four main groups: irritants, asphyxiants, volatile drugs, and volatile inorganic poisons.

Irritant Gases.

An irritant gas is one which is capable of injuring any tissue with which it comes in contact; the injury is followed by inflammation. The action of all the irritant gases is essentially the same; nevertheless, the symptoms which follow their inhalation are different. Thus ammonia gas causes immediate coughing, sneezing, and severe inflammation of the throat and larynx, while phosgene does not give rise to any marked symptoms at the time of inhalation, but death may follow some hours later from the inflammation induced in the lungs.

The difference in the symptoms caused by the various irritants results from the difference in the localities in the respiratory tract which they attack. The point of action of an irritant is determined by its physical and chemical characteristics, particularly its solubility. Thus a gas which is very soluble in water is taken out of the inspired air by contact with the first moist tissue which it reaches. Less soluble irritants spread their action more extensively along the respiratory tract. Slightly soluble irritants, or those which liberate their irritant principle only on hydrolytic decomposition, affect the upper respiratory tract only slightly, for little of the substance is absorbed there. The main damage is done deep in the lungs. The deeper in the respiratory tract the irritant acts, the more serious are the consequences.

Acid fumes and ammonia are typical of very soluble irritant gases. The injury from their inhalation is largely limited to the upper

respiratory tract. In fatal poisoning by this type of irritant, death results from the swelling of the larynx which shuts off the trachea and thus causes suffocation.

Chlorine and sulphur dioxide are typical of moderately soluble irritant gases. Their inhalation is almost immediately followed by coughing and sneezing. The inflammation which they cause is particularly severe in the trachea and bronchial tubes. This inflammation is often followed by infection with bacteria from the mouth and throat; bronchitis and bronchopneumonia result.

Nitrogen peroxide and phosgene are typical irritant gases of low solubility. They act largely upon the lungs and cause death from edema of the lungs. Fluid from the blood seeps through the walls of the alveoli and clots in the air spaces, thus preventing the blood from being aerated. When lung edema occurs, it develops from twelve to twenty-four hours after exposure to the irritant and is usually fatal. Nitrogen peroxide arises as reddish brown fumes from the action of nitric acid upon organic material. Phosgene has been used as a war gas; it may also be formed when carbon tetrachloride is sprayed upon heated surfaces.

Infection After Exposure to Irritant Gases.

Men poisoned by irritant gases usually either die within a few days or appear to recover completely. Chronic inflammations or scarring may, however, result in the bronchi or lung tissue, with areas of persisting infection and abscesses. The general health may thus be impaired for a long time. Persons thus afflicted frequently appear normal when at rest, even under medical examination, but they are incapable of anything more than the most moderate exertion.

Inflammation of the lungs caused by irritant gases does not lead directly to tuberculosis, as is the case with irritation from silica dust. The statistics of the subsequent health of soldiers gassed during the war indicate that when the lungs are healed they are not appreciably more liable to tuberculosis than would otherwise have been the case. On the other hand, when the man has suffered a period of decreased vitality or ill health as a consequence of the action of an irritant gas, then a tubercular infection already present may gain headway as it might during ill health from any other cause.

Prolonged exposure to sublethal concentrations of irritants may induce chronic poisoning; the chief effect is a moderate inflammation of the respiratory tract, and the chief symptom a sharp cough. If the

exposure is a more or less regular part of the man's working conditions, the inflammation passes into a chronic catarrhal state. The cough then becomes a less marked feature and the worker appears to have acquired a partial tolerance to the gas. No true tolerance exists, however; the cough is less active merely because of the protection afforded the mucous membranes of the upper portion of the respiratory tract by the tenacious mucus with which it is coated. This protection does not extend to the tissues of the deeper bronchi or lungs; it rather exposes them the more because the worker can now tolerate the irritant gas with less immediate discomfort and for a longer time.

Asphyxiant Gases.

An asphyxiant gas or vapor is one which induces suffocation by some means other than prevention of breathing. Gases which are inert physiologically, such as hydrogen, nitrogen, and methane, act as asphyxiants by diluting the oxygen of the air so that it becomes insufficient for the needs of the body. Carbon monoxide and the volatile cyanide compounds induce asphyxia through their effects after absorption. Carbon monoxide combines with the hemoglobin so that the blood cannot carry sufficient oxygen for the needs of the body. Cyanides affect chiefly the tissues themselves, so that they are unable to use the oxygen which is brought to them.

Symptoms of Asphyxia.

The nervous system is more sensitive to deprivation of oxygen than is any other tissue. Asphyxia of mild degree or short duration partially abolishes the function of the nervous system and leads to unconsciousness; severe asphyxia maintained even for a short time may injure the nervous system irremediably. The symptoms arising from asphyxia depend upon the degree and duration of the oxygen deprivation suffered by the nervous system. In severe asphyxia such as that induced by inhalation of pure nitrogen, or even a low concentration of hydrocyanic acid gas, unconsciousness develops at once, the man falls to the ground as though struck by a blow on the head; if the asphyxia continues, he dies within a few minutes. In less severe asphyxia the symptoms develop more slowly; in many respects they then resemble those of alcoholic intoxication. The ability to maintain attention is diminished, as is also the coordination for such finer skilled movements as writing. Next the judgment and emotions, particularly the temper, become affected. Muscular effort performed at this stage

leads to rapid fatigue and exhaustion. Asphyxia of greater degree is followed by inability to perform such muscular movement as walking. The first effect noticed by the man undergoing the asphyxia may be his inability to move. Unconsciousness soon follows. Breathing stops, but the heart continues to beat for six or eight minutes longer. Death follows.

Asphyxia is not painful, although the recovery from it is. If the asphyxiation has not been prolonged and is relieved at any stage short of failure of breathing, the symptoms usually pass off quickly, and aside from the headache and nausea the effects are not often serious. If breathing has stopped it does not as a rule become reestablished unless artificial respiration is performed.

Simple Asphyxiation.

Nitrogen is the principal constituent of the "black damp," and methane of the "fire damp" encountered in mines. A man can breathe air containing 30 per cent or even more of nitrogen or methane without discomfort; the oxygen of the air is thus reduced from the normal 21 per cent to 14.7 per cent. An atmosphere which will support the combustion of a candle contains sufficient oxygen to support life (see Chapter VIII). In making the flame test the danger is that the methane which is abundant in some coal mines will be ignited; the "safety lamp" of miners is shielded with wire gauze to prevent such explosions. It also enables the miner to estimate the amount of methane from the appearance of the cap (the burning methane above the flame) of his lamp. The flame test does not show the presence of noxious gases such as carbon monoxide, gasoline fumes, etc. It is unsafe to make this test in the presence of explosive vapors (i.e., as in testing the air in a tank that has been emptied of benzol or volatile petroleum products) unless a properly designed safety lamp is used. The most satisfactory test under such circumstances is made with an animal such as a mouse placed in a cage and lowered by a cord into the air suspected of contamination. If the mouse survives without any ill effect after one hour, the air may be considered safe for men for an exposure of the same length of time.

Asphyxiation resulting from incarceration in an air-tight inclosure such as the vault of a bank, is rare. The length of time that a man can exist under such circumstances can be readily calculated. A preliminary point to be considered is the fact that few structures, other than metal vaults, are air-tight; the plastered walls of the ordinary

room, or even thick concrete walls, admit air with sufficient freedom to keep the oxygen of the room from being appreciably diminished, even when occupied by many people; carbon dioxide is even more diffusible. The length of time a man can remain in an air-tight inclosure without suffering seriously from asphyxia depends upon the volume of oxygen consumed and the volume of air present. At rest the average man consumes 200 to 300 cubic centimeters of oxygen per minute. A period of seven hours would thus be required to reduce the oxygen in one cubic meter of air to one-half its normal content, an amount still sufficient to support life.

Carbon Monoxide.

Carbon monoxide is the most common of the noxious gases; more deaths result from inhalation of carbon monoxide than from all the other noxious gases combined.

Carbon monoxide is colorless and nearly odorless, and when ignited burns with a blue flame. It is produced by the incomplete combustion of carbonaceous material, and by the partial deoxygenation of carbon dioxide when the latter is passed over red-hot coals.

Illuminating gas is a common source of carbon monoxide. Two types of this gas are manufactured: coal gas and water gas. The former is made by the destructive distillation of coal; it contains from 4 to 8 per cent of carbon monoxide. Water gas is made by passing steam over red-hot coke; it contains about 40 per cent of carbon monoxide. Most cities in America are supplied with illuminating gas containing both coal gas and water gas. The percentage of carbon monoxide ranges between 10 and 30 per cent.

About one-half of all fatalities from carbon monoxide poisoning are due to suicide; the others are caused by accidental leakage of the gas. One of the common causes of accidents is the rubber hose connection used to attach portable gas stoves and lamps to the gas cock. Rubber hose deteriorates with age, and leaks, and the ends are often accidentally pulled from the stove or cock. The company which sells the illuminating gas has no control over the use of hose connections by the consumer; the jurisdiction of the company ceases at the meter, at which point the gas becomes the property of the consumer. Some cities and states have wisely prohibited the use of hose for making gas connections.

The gas generated in blast furnaces contains approximately 25 per cent of carbon monoxide. Gas poisoning about blast furnaces is espe-

cially dangerous, for there the partially asphyxiated man is liable to accidents such as falls or burns. The principal poisonous element in coal smoke is carbon monoxide. Whole households have been poisoned by a leak of smoke through a crack in the dome of a hot-air furnace. When firemen are overcome by smoke it is usually carbon-monoxide poisoning from which they are suffering.

The exhaust gas from internal-combustion engines contains carbon monoxide. The percentage of this constituent in the exhaust varies with the completeness of combustion, and this in turn depends upon the proportion of gasoline and air in the mixture drawn into the cylinders. The "richer" the mixture, the higher is the percentage of carbon monoxide formed. From the excessively rich mixture made by "choking" the carburetor inlet when starting the cold engine, 10 per cent or even more carbon monoxide may appear in the exhaust. When the carburetor is adjusted to give the leanest mixture upon which the engine will run at all, the exhaust contains only a fraction of 1 per cent of carbon monoxide. Starting with the rich mixture from the choked carburetor, the power developed by the engine increases as the mixture is made leaner. The maximum of power is reached, however, before the mixture is thinned to the point of lowest carbon monoxide production. The carburetor adjustment on most automobiles is set for a maximum power and smoothness of operation; it furnishes a mixture which produces a large amount of carbon monoxide, ranging usually from 5 to 7 per cent. The amount of carbon monoxide produced varies with the size of the engine and the speed at which it is run. The average passenger car or truck produces about one cubic foot of carbon monoxide per minute for each twenty horsepower.

When automobiles are operated out-of-doors the exhaust gas does not usually constitute a serious health hazard. In the traffic congestion in large cities, however, the street air may be contaminated with more than 0.01 of one per cent of carbon monoxide, which is considered the maximum for prolonged exposure. Headache and irritability of temper may result in those who are exposed for long periods to the contaminated air. Those in the street are not the only persons exposed to this air, for in the winter time at least, much of the air with which tall buildings are ventilated enters at the street level. Thus the gas may be spread by stairways and elevator shafts to all parts of the building, even to the highest stories.

The replacement of the common horizontal exhaust pipe with one extending vertically and opening above the top of the car has been

suggested as a means of lessening the contamination of the air in city streets. The hot gases coming from the exhaust tend to rise; if they start near the ground, as is the case with the horizontal exhaust pipe, all of the air above this level is contaminated, but if the exit is above the top of the car and thus over the heads of the occupants and pedestrians, the latter are left in an area of air which is not contaminated. The use of vertical exhaust is even more important when the engines of cars are run indoors.

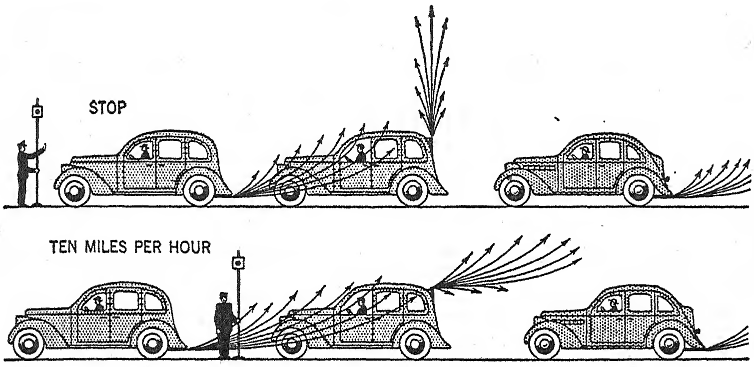


Figure 34. VERTICAL EXHAUST.

Upper line, distribution of exhaust gas from cars standing still with engines running; first and third cars have horizontal exhaust; second car, vertical exhaust. Lower line, distribution of exhaust gas when cars are running at 10 miles an hour.

An automobile or other internal-combustion engine operated indoors constitutes a serious health hazard unless measures are taken to prevent contamination of the air. Many deaths result in the winter months in private garages from running the motor of the car with the garage doors closed. These buildings are usually small, and concentration of carbon monoxide rises almost immediately to a dangerous level. Running the average motor car for five minutes in a garage with dimensions of 12 x 12 x 10 feet will result in a concentration of some 0.3 of one per cent of carbon monoxide; if the engine is cold and the mixture enriched to assist starting, a concentration as high as 1 per cent of carbon monoxide may develop. These concentrations rapidly cause disablement, unconsciousness and death. The effects come on suddenly and without warning. The legs are paralyzed first, the person exposed to the gas falls and is unable to rise or even crawl.

In large public garages, motor repair shops, testing rooms, freight warehouses, mines, tunnels, or any other inclosed space where automobiles are operated, serious results may follow from the contamination of the air with exhaust gases. The concentration of carbon monoxide does not rise as rapidly or as high as in a small garage, but the exposure is longer and the men who work in the contaminated air suffer in health. They have headache, their temper is irritable, their judgment is affected, and their efficiency is reduced. General ventilation usually fails to reduce the carbon monoxide to a harmless concentration, and is effective only under special and suitable circumstances such as in the vehicular tunnels under the Hudson River. In the case of the passengers using the tunnels the exposure is limited to a short time, a quarter or at most a half hour.

Automobile exhaust may prove a source of danger even out-of-doors when the person operating, loading or unloading a truck stands in the rear of the car while the engine is allowed to idle. The air in line with and within a few feet of the exhaust pipe contains a high concentration of carbon monoxide. Repeated exposure may result in the absorption of a sufficient amount of the gas to cause some degree of poisoning. Carbon monoxide affects the judgment like alcohol. The person intoxicated by either is unaware of his faulty judgment, but his liability to accidents is greatly increased.

Action of Carbon Monoxide.

Carbon monoxide is poisonous because it combines with the hemoglobin of the blood and prevents this substance from transporting oxygen to the tissues. Aside from this one reaction in the body, carbon monoxide is an inert gas. It is neither burned nor otherwise destroyed in the body; and when pure air is again breathed the gas that has been previously absorbed is gradually eliminated. Carbon monoxide itself does not harm the tissues of the body; the poisonous effects which follow the inhalation are the secondary results of the asphyxia occurring during the time the hemoglobin is combined with carbon monoxide.

Both oxygen and carbon monoxide combine with hemoglobin; therefore when hemoglobin is exposed to the two gases, as when air contaminated with the gas is breathed, each gas combines with the hemoglobin in a proportion determined by two factors: (1) the amount of each gas present, and (2) the relative attraction which each exerts

toward hemoglobin. The reaction of hemoglobin in the presence of carbon monoxide and oxygen is expressed by the equation:

$$\underset{\text{(oxyhemoglobin)}}{HbO_2 + CO} \leftrightarrows \underset{\text{(carbon monoxide hemoglobin)}}{HbCO + O_2}$$

The attraction between carbon monoxide and hemoglobin is about 300 times as great as that between oxygen and hemoglobin. Therefore when the air to which blood is exposed contains 1/300 as much carbon monoxide as oxygen, one-half of the hemoglobin combines with the carbon monoxide, and half with oxygen. Hemoglobin in combination with carbon monoxide is useless in the body; the blood is deprived proportionately of its ability to carry oxygen. Pure air contains 21 per cent of oxygen; therefore when air containing 0.07 of one per cent ($1/300 \times 21$) of carbon monoxide is inhaled, the gas will combine with and render useless one-half of the hemoglobin in the blood. The displacement of half the oxygen in the blood by carbon monoxide results in a degree of asphyxia verging on unconsciousness.

Although the inhalation of 0.07 of one per cent of carbon monoxide will displace one-half of the oxygen from the blood, the inhalation must be continued many hours before this end is reached. This time would be required for a sufficient volume of air and carbon monoxide to be breathed. The body of a man of average size contains at least five liters of blood, and the hemoglobin of this amount of blood has a capacity of approximately one liter of oxygen (20 volumes per cent). The blood would combine with the same volume of carbon monoxide. With a volume of breathing of eight liters per minute and with 0.07 of one per cent of carbon monoxide in the air, only 0.0056 of a liter of carbon monoxide are inhaled each minute. Of this, only about two-thirds reach the lungs, so that only 0.0036 of a liter are absorbed into the blood. If the rate of absorption were uniform, three hours would be required for 50 per cent of the hemoglobin to be combined with carbon monoxide. In reality, however, the rate of absorption decreases as the percentage of carbon monoxide hemoglobin in the blood increases, so that ten or twelve hours of exposure are required to effect a 50 per cent combination. The rate of absorption is proportionately greater with higher concentrations of carbon monoxide in the air, and also with the greater volume of breathing resulting from exercise.

The size of the individual also has an influence upon the time required for a certain percentage of the blood to combine with carbon monoxide. The volume of blood in the body varies with the weight;

the metabolism, and hence the volume of air breathed, vary with the surface area of the body. The smaller the animals the greater is the surface in relation to the weight, and so to the volume of blood; the rate of saturation of the blood with carbon monoxide varies inversely with size. Babies succumb to carbon monoxide more quickly than adults; while a very small animal, such as a mouse or a canary, is overcome in about one-twentieth the time required for a man. Mice and canaries are frequently used to indicate the presence of dangerous amounts of carbon monoxide in the air of mines. After the animal has collapsed there is still time enough for the men to escape.

The harmful effects of carbon monoxide depend upon the proportion of oxygen displaced from the blood and the length of time this oxygen deficiency persists. The combination of 15 per cent or less of hemoglobin with carbon monoxide does not give rise to any noticeable symptoms. As the combination of 15 per cent of the hemoglobin with carbon monoxide is equivalent to equilibrium with 0.01 of one per cent of carbon monoxide in air, this concentration is the highest properly allowable for any long exposure. The air in the streets of some of our cities, as, for instance, Fifth Avenue, New York, shows at times a concentration higher than this from the exhausts of automobiles. Concentrations higher than 0.01 of one per cent can be tolerated if the period of exposure is shortened so that no more than 15 per cent of the hemoglobin enters into combination with the carbon monoxide. Thus, for the vehicular tunnel under the Hudson River a maximum of 0.04 of one per cent has been adopted as the standard for an exposure not to exceed one hour.

Severe headache and some emotional disturbance may result when 15 to 30 per cent of the hemoglobin is in combination with carbon monoxide. These symptoms are exaggerated by any exertion. More oxygen is used by the body during exercise and the impairment in its transportation is felt more acutely. Thirty to 50 per cent saturation of the blood with carbon monoxide may cause very severe headache, shortness of breath, and nausea; if exercise is attempted, fainting may result. Sixty per cent saturation brings unconsciousness, and any higher saturation may result in death.

As low as 0.1 of one per cent of carbon monoxide in air will cause unconsciousness and death if the exposure is prolonged; 1.0 per cent will kill in a very few minutes. The following table summarizes the effects of exposure to various concentrations of carbon monoxide in

relation to the time of exposure. The concentrations given are parts of carbon monoxide in 10,000 of air, and the time is in hours:

1. Time × concentration = 3, no perceptible effect.
2. Time × concentration = 6, a just perceptible effect.
3. Time × concentration = 9, headache and nausea.
4. Time × concentration = 15, dangerous.
5. Time × concentration = 25, deadly.

Thus 0.1 of one per cent or 10 parts of carbon monoxide in 10,000 of air gives no perceptible effect for an exposure of twenty minutes ($1/3 \times 10 = 3$), but would be dangerous for an exposure of 1½ hours ($3/2 \times 10 = 15$).

When the person returns to fresh air after exposure to carbon monoxide, the gas which has been absorbed is eliminated at a rate which depends largely upon the volume of air breathed. During the period of elimination the asphyxia continues in a degree depending upon the carbon monoxide still in the blood. Rapid elimination of the gas is therefore extremely desirable, for it lessens the harmful effects of the asphyxia by shortening its duration. The inhalation of dilute carbon dioxide (to be discussed under resuscitation from asphyxia) is now widely used to stimulate the breathing and thus to hasten the elimination of carbon monoxide.

Cyanide Compounds.

The cyanides when brought into contact with living matter arrest oxidation by acting upon the catalysts through which the oxidations are carried out. Asphyxia thus results because oxygen cannot be utilized. Poisoning by the inhalation of cyanide vapor is rare except from hydrocyanic acid gas, which is used for fumigation. The symptoms which arise from the inhalation of cyanide resemble those from carbon monoxide, but develop much more rapidly; indeed, the cyanides are among the most rapidly fatal of all poisons. The absorbed cyanide is converted in the body into harmless compounds, and if the amount absorbed has not been too great, life can be saved by maintaining artificial respiration.

Volatile Drugs.

The most common of these substances are the volatile hydrocarbons from petroleum and coal tar and the various alcohols, ethers, and esters used in industry. All of these substances act more or less like alcohol in producing drunkenness, and in the same manner as the anesthetics

used for surgical operations. The hydrocarbons from petroleum cause intoxication similar to that of ethyl alcohol, and unless death occurs in the acute stages of the poisoning there are usually no serious after-effects. The hydrocarbons from coal tar not only produce intoxication, but in addition after prolonged exposure they cause destruction of various tissues in the body and other serious after-effects. The compounds of methyl, such as methyl alcohol and methyl bromide, although not derived directly from coal tar, exhibit in high degree the destructive action upon certain tissues. Numerous cases of blindness have followed the inhalation of the vapors of wood alcohol from lacquer applied in confined quarters.

Volatile Inorganic Poisons.

Of these inorganic substances the most important are phosphorus, mercury, and hydrogen sulphide. Mercury alone among the metals has a sufficiently high volatility to permit poisoning from its vapors. The fumes arising from other metals in the molten state are dust resulting from the condensation of the vapors evolved only at high temperatures. Metals such as lead when in the form of volatile organic compounds such as tetraethyl lead may, however, be absorbed through the lungs.

Mercury is volatile, even at room temperature. Mercury spilled upon wooden or concrete floors or upon carpets and mixed with dirt breaks into minute globules which expose a large surface for evaporation. Poisoning in this way may result from the spilling of relatively small amounts of the metal. The inhalation of the vapor causes changes in the gums leading to pyorrhea, intestinal disturbances, and changes in the nervous system involving tremor of the hands and a peculiar type of embarrassment.

The vapor of phosphorus when inhaled over a long period causes changes in the bones so that their resistance to bacteria is reduced. The teeth decay, with the introduction of pus into the jawbone, and this is followed by the destruction of the entire jaw (phossy jaw). The gruesome deformity formerly caused by inhaling phosphorus vapor during the manufacture of matches led to the abolition of the use of white phosphorus for this purpose.

Hydrogen sulphide is formed by the decomposition of organic material. It occurs in sewer gas, and is evolved during the manufacture and use of dyes, the purifying of coal gas and the distillation of petroleum oils containing sulphur. The gas has a smell characteristic of

rotten eggs. In very low concentrations hydrogen sulphide irritates the eyes and causes an inflammation resembling pink eye. In higher concentrations it paralyzes respiration. Hydrogen sulphide is nearly as poisonous as cyanide and in high concentrations it is one of the most rapidly fatal of all poisons.

Protective Apparatus.

Three types of apparatus are used for protection against the inhalation of noxious gases: (1) gas masks, (2) hose masks, and (3) self-contained breathing apparatus. These three forms of apparatus differ from one another in principle, and each has advantages and disadvantages in relation to the other types. Each is best for its own special use. The greatest care should be taken to avoid inadequate or defective protective apparatus, for it may add the death of a rescuer to that of a first victim. As such apparatus, especially the rubber parts, deteriorates rapidly, it must be frequently inspected and regularly renewed.

Unfortunately, there is a widely held belief that a handkerchief or some other piece of fabric tied over the mouth and nose constitutes a gas mask. Many lives have been sacrificed to this fallacy. Fabrics that will permit the passage of the respired air will also permit the passage of noxious gases. Moistening the cloth offers protection against only a few substances and for only a short time. The more soluble irritant gases and vapors, when present only in low concentrations, may be partially and temporarily absorbed by the moisture; but such makeshift arrangements offer absolutely no protection against the asphyxiants and the volatile drug-like substances. Respirators designed to prevent the inhalation of dust alone, afford no protection against noxious gases.

Gas Masks.

A properly constructed gas mask consists of a facepiece of rubber or rubberized fabric, which fits tightly across the forehead, along the cheeks and under the chin, and which is connected by a short piece of flexible and non-collapsible tube to a sheet-metal canister containing absorbent materials. The facepiece is fitted with windows of non-splintering glass placed in front of the eyes. The canister is worn suspended from the shoulders or strapped across the chest. At the bottom of the canister is a light disk check valve which opens only to admit air, so that the breath is drawn in through the canister. A second valve

opens from the facepiece to the outside air; through this valve the breath is exhaled. The canister is filled with layers of various materials which remove, either by absorption or by chemical reaction, certain gases and vapors from the air. When the mask is fitted to the face all

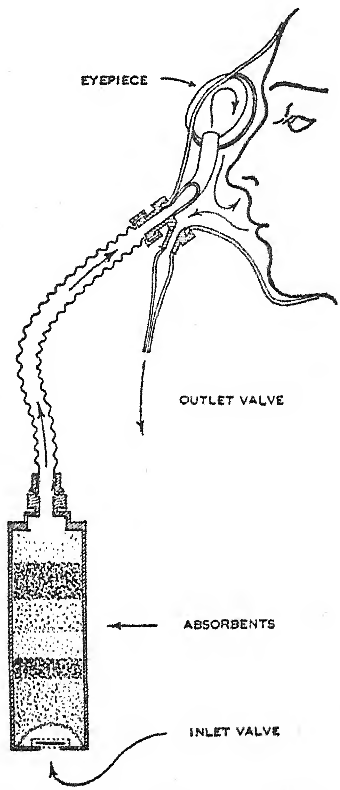


Figure 35. SCHEMA OF GAS MASK.

of the air inspired is filtered through these materials and is thus purified.

The gas mask in its present form is the highly developed and extremely efficient product of extensive and careful investigation. It is light, quickly applied, allows freedom of movement and is purchasable at a reasonable price. It affords effective protection against such gases and vapors as the materials in the canister are designed to absorb. Most canisters are charged with materials intended to absorb only a limited number of closely related gases. The contaminant in the air

must be known and the proper canister employed to absorb that type of gas. A canister charged to afford protection only against ammonia, for example, is useless for such gases as carbon monoxide or hydrochloric acid fumes; for each of those gases there is a special type of absorbent. There is one type of canister, however, the so-called "all-service canister," which gives protection against all gases and vapors found in industry, excepting, of course, high concentrations of the simple asphyxiants. This type of canister is useful when the contaminant in the air is unknown, as is the case when firemen enter chemical storage depots; but it has the disadvantage of a relatively short life, because of the comparatively small supply of each absorbent in the canister when used against any one particular gas. In most industrial plants the gases which may occur are known beforehand, and the proper canisters should be provided. Canisters filled with only one type of absorbent material afford protection for a longer time than is possible with the all-service canister.

A stripe painted on the canister indicates that it is fitted with filter pads and will protect against smoke, dust, and mists. A gas mask cannot be safely used in an atmosphere seriously deficient in oxygen. The practical limit beyond which a mask should not be used is indicated by the extinction of the flame of a candle or safety lamp. This occurs at about 17 per cent of oxygen in the air; a man is not in serious danger until the oxygen falls below 14 per cent. When, because of an excess of the simple asphyxiant gases, the oxygen falls below this limit, a gas mask ceases to afford protection, even though the absorbent in the canister removes any actively toxic gas. Under such circumstances a hose mask or self-contained breathing apparatus must be used.

Hose Masks.

The facepiece of a hose mask is essentially the same as that of a gas mask; but instead of the inspired air entering through a canister it is brought in through a length of hose, the outer end of which is supplied with fresh air. If the hose is over twenty-five feet in length, or if the worker must wear the mask for a considerable time, air should be blown in with a pump. In an emergency a bellows or even a jet of compressed air may be used. The latter is not to be recommended, however, for the air may contain oil. If a jet of compressed air is used the hose should be left open at the end, and the jet should be shot in on the principle of an injector. Whenever possible, the air blower for a hose mask should be of the centrifugal type, so that in

case it is run at too low a speed or stops entirely the air supply will not be cut off; for enough air may be drawn through a centrifugal pump and even a long hose to permit the wearer of the mask to escape from an irrespirable atmosphere.

The hose mask is especially desirable for work in atmospheres contaminated with the vapors of the lighter petroleum distillates. In such vapors the life of the canister of a gas mask is of uncertain duration and poisoning may be rapid when the canister becomes exhausted. A

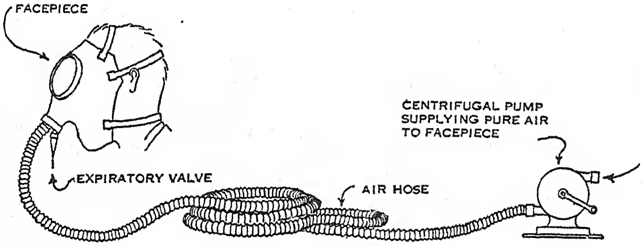


Figure 36. HOSE MASK.

self-contained breathing apparatus may also fail, for the vapors may penetrate the rubber fabric and accumulate in the circulated oxygen. A hose mask can be worn in any atmosphere regardless of oxygen content. Its only disadvantage lies in the fact that the wearer's activities are limited by the length of the hose.

Self-contained Breathing Apparatus.

A self-contained breathing apparatus is a portable device for supplying an atmosphere of oxygen which the wearer continually rebreathes, while the carbon dioxide which he exhales is absorbed by an alkali. It consists of a facepiece or mouthpiece fitted with two valves, one inspiratory, the other expiratory. To the inspiratory valve is attached a piece of rubber fabric. A similar tube from the expiratory valve goes to a canister of soda lime, and another tube from there to the bellows or bag. The bag is automatically filled with oxygen from a cylinder of the compressed gas, which is carried as part of the apparatus. The automatic feed keeps the bag at all times adequately filled by admitting more oxygen whenever the bag collapses to a certain point. When the breath is inspired, oxygen is drawn from the bag; when it is expired, the breath passes through the soda lime which removes the carbon dioxide. The purified exhaled oxygen then goes into the bellows

to be reinspired. By this circulation oxygen is drawn from the cylinder only in amounts sufficient to replace that consumed by the wearer.

Self-contained breathing apparatus is available in two general types; one can be safely used for thirty minutes, and the other for two hours. The first weighs from fifteen to seventeen pounds, and the latter thirty to forty-five pounds. After the apparatus has been run for the specified time, the cylinder of oxygen must be replaced by a new one, and the soda lime must be renewed in the canister.

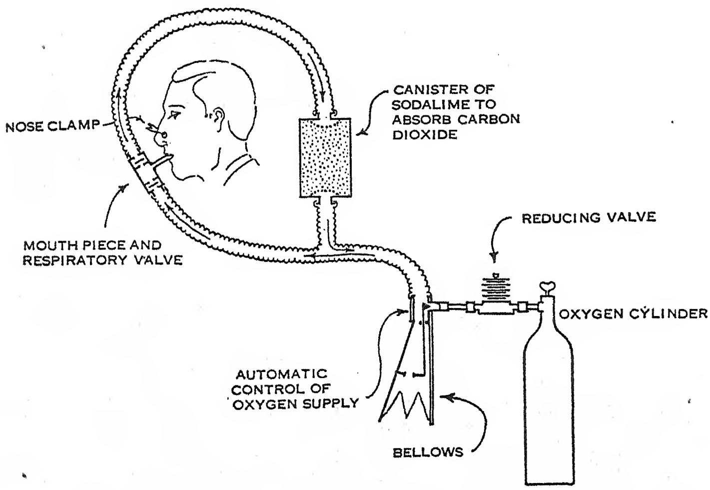


Figure 37. SCHEMA OF SELF-CONTAINER BREATHING APPARATUS.

Self-contained breathing apparatus has the same general application as the hose mask. It has a marked advantage over the latter in that the wearer's movements are not restricted by a long hose to the outer air, and he may therefore penetrate as far as he needs into passages and chambers filled with an irrespirable atmosphere. But self-contained breathing apparatus has the disadvantage of being heavy and cumbersome; it is expensive and the rubber portions deteriorate rapidly. It is a complicated piece of apparatus, and for its proper operation requires frequent inspection and adjustment. The apparatus is largely used in mine rescue work and to some extent by firemen. For purposes of exploration and rescue work over considerable distances in atmospheres deficient in oxygen where the flame of a safety lamp is extinguished, self-contained breathing apparatus is the only means available. On the other hand, for use even in very poisonous atmospheres

in which there is sufficient oxygen to support a flame, the gas mask and the canister afford not only more practical working conditions for the wearer, but also a greater degree of safety, certainly with far less liability to accident. Unsuspected defects in self-contained apparatus have cost many lives; a small unnoticed crack in one of the rubber parts imposes the penalty of death. No one should ever attempt to use this form of apparatus unless he has been thoroughly trained in its use and knows that his particular apparatus is in perfect order.

Treatment of Acute Poisoning by Noxious Gases.

The proper first-aid treatment of poisoning by noxious gases and vapors is the most important step in saving the life of the man who

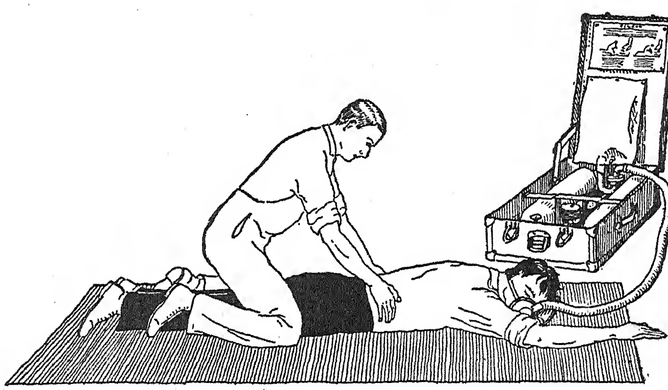


Figure 38. Artificial Respiration by the Prone Pressure Method—Position 1. The artificial respiration is being given here in conjunction with the inhalation of oxygen and carbon dioxide by means of the H-H inhalator. The return of spontaneous breathing is expedited by the inhalation.

has been gassed; his life is often in the hands of the first arrival and the outcome depends upon the practice of the proper procedures. The doctor who treats the patient after he is taken to the hospital has far less influence on the final outcome.

The first step is to remove the man from the contaminated atmosphere and to bring him as rapidly as possible into uncontaminated and preferably warm air.

A warning is necessary at this point: The rescuer must not breathe the gas himself even for a short time. No one is immune to the action of noxious gases. The well-intentioned rescuer who walks into an atmosphere of gas and succumbs gives no assistance to the original

victim and merely adds to the work of subsequent rescuers. His action is similar to the common occurrence when a man, who himself cannot swim, jumps into deep water because he sees another man drowning. Such procedures are not heroic; they are silly. There are occasional conditions in which it is possible to enter a short distance into gas-contaminated air and to drag out an unconscious man; but the rescuer should not attempt this without having a line tied round him and held by someone outside. It is usually wiser to open the doors and windows from the outside and to allow fresh air to sweep the gas from the room before the rescue is made. The proper procedure for rescue, however, consists in wearing a suitable gas mask, hose mask, or (if fully trained in its use) a self-contained breathing apparatus, together with a belt and safety line.

The victim should be removed from the poisonous atmosphere and placed in fresh, but not cold, air. In cold weather indoor air is preferable to outdoors. Chilling should be carefully avoided after any form of gassing. The victim should be wrapped in blankets. Hot-water bottles and heated bricks are often recommended, but they are more dangerous than beneficial in the hands of the overzealous; a man does not complain of being burned while he is unconscious, but the burns that result from hot-water bottles or other heated objects placed next to the skin are in many cases the most serious sequel to the gassing.

Acute poisoning by any one of the asphyxiants leads to respiratory failure. This is true also of the majority of the volatile drugs and drug-like substances. Whenever breathing has ceased for this reason, artificial respiration should be started at once by the prone pressure method. The procedure of the prone pressure, or Schafer, method is as follows:

1. Lay the patient on his belly, one arm extended directly overhead, the other bent at the elbow, with the face turned to one side and resting on the hand or forearm so that the nose and mouth are free for breathing.

2. Kneel, straddling the patient's hips, with your knees just below the patient's hipbones or the opening of his pants pockets. Place the palms of your hands on the small of the patient's back with fingers over the ribs, the little finger just touching the lowest rib, the thumb alongside of the fingers, the tips of the fingers just out of sight.

3. While counting one, two, and with the arms held straight, swing forward slowly, so that the weight of your body is gradually, but not

violently, brought to bear upon the patient. This act should take from two to three seconds.

4. While counting three, swing backward so as to remove the pressure.

5. While counting four, five, rest.

6. Repeat these operations deliberately, swinging forward and backward twelve to fifteen times a minute, thus making a complete respiration in four or five seconds.

7. As soon as artificial respiration has been started and while it is being continued, an assistant should loosen all tight clothing about the patient's neck, chest, and waist, and wrap the patient warmly in a blanket.

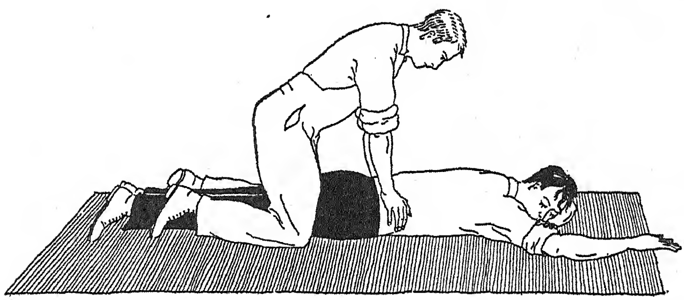


FIGURE 39. ARTIFICIAL RESPIRATION BY THE PRONE PRESSURE METHOD—POSITION 2.

8. Continue artificial respiration without interruption until natural breathing is restored, if necessary for several hours, or until a physician declares *rigor mortis* (stiffening of the body) has set in. Do not stop merely because he says the patient is dead; you may be able to revive him. If natural breathing stops after being restored, use this method of resuscitation again.

The procedure outlined here for the rescue and resuscitation from noxious gases is applicable to the treatment of drowning. In drowning it is unnecessary and inadvisable to attempt to remove water presumed to be in the lungs by any special procedure such as lifting the victim in the middle or rolling him on a barrel. Valuable time is thus lost and no advantage is gained.

There are several types of apparatus designed to give artificial respiration. Some, such as the Drinker respirator, used largely to treat the victims of infantile paralysis, have their definite place in the hospital; none, however, are suitable for rescue work, even though they

are made portable and are designed and sold for this purpose. Time is the most essential factor in resuscitation; every minute lost after breathing has stopped and before artificial respiration is begun decreases the chance of recovery. Within ten minutes at most, more probably within five or less, the last chance is lost. Manual artificial respiration can be started in a few seconds by the first person who arrives at the spot where a man has been gassed. By contrast it takes many minutes to unpack, adjust, and start the mechanical devices, even in the rare instances when they are at hand. Usually they are at some

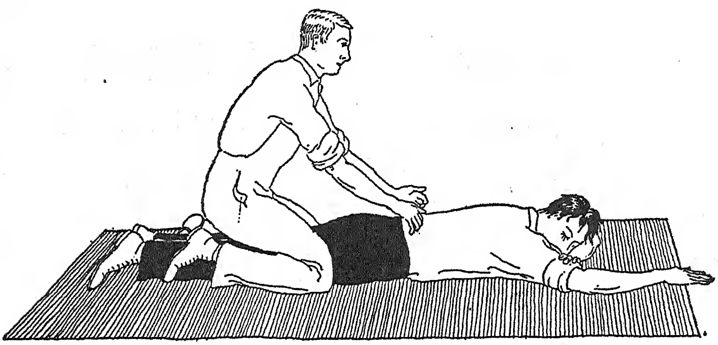


Figure 40. Artificial Respiration by the Prone Pressure Method—Position 3.

distance and many minutes are lost in bringing them to the spot. Instead of immediately initiating manual artificial respiration, the rescuer waits for the device to arrive; the patient in the meantime dies. The greatest objecton to mechanical devices is the fact that when reliance is placed upon them general training in the prone pressure method is discouraged.

Treatment by Inhalation of Oxygen and Carbon Dioxide.

The inhalation of a mixture of oxygen and 7 to 10 per cent of carbon dioxide after poisoning by the noxious gases and vapors greatly assists in the restoration of normal breathing and hastens the elimination of volatile or gaseous substances which have been absorbed. The carbon dioxide in the mixture stimulates breathing. The inhalation of dilute carbon dioxide influences the respiratory center in exactly the same way as the increased carbon dioxide production resulting from exercise. There is this difference, however, between the increased volume of air resulting from exercise and that from the inhalation of

carbon dioxide: the development of carbon dioxide in the body by exercise necessitates the utilization of oxygen from the blood, a condition which is fatal in carbon-monoxide poisoning; the inhalation of dilute carbon dioxide stimulates the breathing but involves no draft on the supply of oxygen. When oxygen is used in combination with dilute carbon dioxide the displacing action which it exerts upon the carbon monoxide in the blood is brought into play in the most effective manner.

The inhalation of oxygen plus carbon dioxide does not take the place of artificial respiration. If breathing has stopped, manual artificial

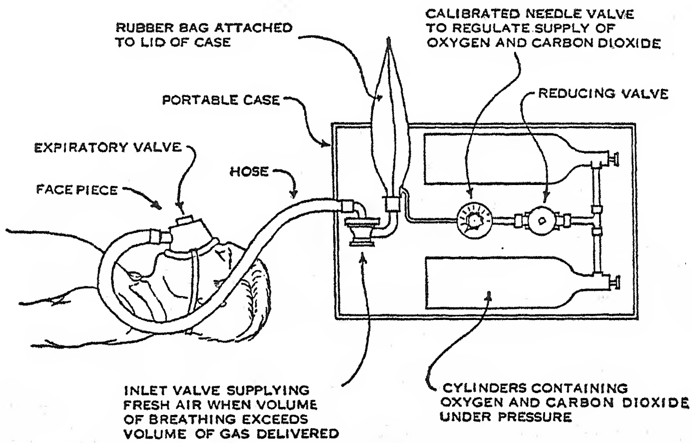


Figure 41. SCHEMA OF THE H-H INHALATOR.

respiration should be administered. The return of spontaneous breathing is hastened, however, if inhalation of the oxygen-carbon dioxide mixture is given while the artificial respiration is being carried out. In order to be fully effective, the inhalation should be given as soon after the gassing as possible. If the person who has been gassed lives for three or four hours the greater part of the carbon monoxide or other gaseous or volatile substances in the blood are eliminated even when air alone is breathed. Thereafter treatment by inhalation is of less benefit. The main purpose of the inhalation of carbon dioxide and oxygen is to attain in twenty or thirty minutes the same degree of elimination of these substances as would be reached in three or four hours of elimination unassisted by inhalation. This treatment is particularly beneficial in poisoning by carbon monoxide, but is applicable

also to poisoning by other gaseous and volatile substances. An especially designed inhalator must be used for the administration of the oxygen and carbon dioxide mixture—the so-called H. H. Inhalator.

Harmful Dusts.

Harmful dusts are divided according to their action into four classes: (1) mechanical irritants; (2) chemical irritants; (3) poisons; and (4) allergic or asthma-producing.

Any inorganic dust present in the air in large amounts may irritate the nose and throat by its roughness, that is, mechanically. Dusts that are chemically irritating, such as lime dust and chromium salts, may corrode the mucous membrane of the nose, producing ulcers. The most harmful of all dusts, silica, does little injury to the upper respiratory tract but causes irreparable damage to the lungs. Its action is both mechanical and chemical. The condition resulting from exposure to this dust is known as silicosis.

In order to reach the lungs dust particles must be exceptionally minute in size. An atmosphere cloudy with coarse dust may cause only irritation of the nose and throat without affecting the lungs, whereas one containing dangerous quantities of very fine dust may appear pure. Silica, coal dust, and carbon particles from smoke are small enough to be carried on the stream of air through the sharp bends in the nasal passage. Coal dust and carbon dust do not ordinarily injure the lungs even when the lungs are rendered blackish in color from the deposited dust. Silica injures the lungs. The sharp particles cause mechanical irritation. This effect is, however, less important than the changes produced by a chemical action of the dust. The lung tissue is inflamed; cells multiply and block the lymph channels; the lungs are scarred—a condition known as fibrosis.

The fibrosis of silicosis may develop within a few years of exposure. It greatly predisposes to diseases of the respiratory tract such as pneumonia, but especially to tuberculosis which runs a rapid and fatal course. Dust is the foremost contributing factor to consumption in industry. Centuries ago the writer Agricola made the observations that miners in the Carpathian Mountains suffered so severely from the dust in their occupation that women could be found who had married as many as seven husbands. Silicosis, although preventable, is still prevalent in certain industries.

The most harmful variety of silica is asbestos dust; silica is also present in the dust from granite, flint, quartz, and certain enamels.

Sand contains silica, but ordinary particles of sand are far too large to pass through the upper respiratory tract. Fragments of sand arising during sandblasting or from the use of grinding wheels made of sandstone may be injurious.

Poisoning from dusts occurs in the handling of such substances as arsenical insecticides, lead pigments and tobacco dust. It occurs also from the inhalation of condensed metal vapors such as those of zinc and antimony. The absorption from dust constitutes merely a mode of entry for the poison; the poisonous effects, with the exception of zinc, are no different from those following ingestion of these substances. Zinc as a metal is non-poisonous; but the inhalation of "fumes," oxide of zinc, from the molten metal, and also of brass, which contains zinc, may in susceptible individuals, or even in normal ones when the exposure is excessive, lead to a peculiar transient illness known as "zinc chills" or "brass founders' ague." Zinc stearate used as a dusting powder for infants has occasionally produced bronchopneumonia when inhaled in considerable amounts.

The allergic response to organic dusts results in attacks of hay fever or asthma. This general subject is dealt with in the section devoted to allergies (Chapter XXIII).

Protection Against Dust.

There are three chief methods available for the avoidance of the inhalation of dust: (1) Prevention of the formation of dust; (2) prevention of the escape of dust into the air; and (3) removal of the dust from the air. The choice of the particular method to be used depends upon the circumstances of the occupation. Whichever is adopted, no workman should ever be exposed directly to air contaminated with an excessive amount of any kind of dust, or to any dust containing appreciable amounts of silica or poisonous metallic substances.

In many instances the formation of dust can be minimized by the application of water, oil or steam. The sprinkling of dusty streets with water is an example of this means of preventing dust formation. Water may be used to prevent dust from rising in rock drilling, mining, stone crushing, and in the grinding of metals. Wet methods have also been adopted with advantage in the lead and pottery industries and in sandpapering paint.

When dust formation cannot be prevented, its escape may be limited by inclosing its source. Dust-proof coverings can be made for packing or conveying dusty materials, especially when they are of a poisonous

nature, as in the mixing and boxing of lead pigments. Stone crushing, clay grinding, and similar procedures can be carried out in inclosed machinery. Closed conveyors may be substituted for the open type.

In certain instances in which the use of inclosed machinery is impossible, it is necessary to remove the dust by a current of air. This is done by means of exhaust ventilation. The dust must be removed as near as possible to its point of origin; it is thus prevented from getting into the general atmosphere and a smaller volume of air is necessary to remove it. In some processes it is impossible by any of the methods given to keep the atmosphere free from excessive dust. In these cases dust helmets or respirators should be worn. A dust helmet consists of a light box fitted loosely over the head, with a window, usually of fine mesh wire, in front of the eyes. Compressed air is admitted by a hose attached to the top of the helmet and the air escapes freely from the helmet. A flow of approximately three cubic feet per minute is adequate. An operator equipped with such a dust helmet may work in safety regardless of the dust contamination in the surrounding air. The method is limited by the air hose and can be used only for relatively stationary operations such as sandblasting.

A respirator is a device intended to filter out the dust from the air breathed. It consists of a rubber facepiece covering the mouth and nose and held tightly in place by straps; on the front of the facepiece or attached to it by tubes are paper or fabric filters through which the air is drawn. A well-designed respirator will remove fine particles and may be used with safety even in silica. Few respirators, however, are this competent; most remove only coarse particles, and their use may give a false sense of confidence in atmospheres containing dangerously fine dust. In the presence of corrosive and irritating dusts or those causing allergic reactions any respirator that gives comfortable freedom from irritation or hay fever may be used with safety. If the respirator is to be used in the presence of silica dust, however, it is advisable to select the device only on competent advice based on actual tests of its performance.

Poisons and Caustics.

In addition to dusts and gases there are many harmful substances, both solid and liquid, which may reach the body by way of the digestive tract or be injected hypodermically. This group includes caustics and poisons taken accidentally or with suicidal intent as defined under food poisoning in Chapter II. Included also are narcotics such as mor-

phine and cocaine, anesthetics such as alcohol, stimulants such as caffeine, and depressants such as the pain-deadening medicaments and sleeping preparations used in home medication.

Accidental poisoning is particularly liable to occur among children. In persons under fourteen years of age poisoning (including corrosion) ranks third as a cause of fatal accidents in the home. The substances most commonly taken by children are: *the caustics,* carbolic acid, lysol, iodine, acids such as oxalic, lye, ammonia, kerosene and gasoline; *the poisons,* bichloride of mercury (which is both a caustic and a poison), arsenic, as Paris green or other insecticides, strychnine, which is often an ingredient of laxative pills and tonics, "sleeping" medicines (veronal, luminal, chlorol hydrate, amytal, etc.), and wood or denatured alcohol. The primary steps in preventing poisoning in the home, particularly among children, are:

1. Keep all bottles and boxes labeled and throw away the contents of any from which the label has been removed.

2. Keep all harmful substances separated from medicines; keep both under lock and key.

3. Never take medicine or give it to another from a box or bottle selected in the dark when the label cannot be seen.

In suspected poisoning immediate first-aid attention is needed. If the poison can be removed from the stomach before it is absorbed, severe effects may be averted; after it is absorbed there is usually little that can be done even by a physician. The physician should be called, but first-aid measures should not await his arrival.

Treatment is designed, first, to dilute or neutralize the harmful substance, and second, to wash it out of the stomach. Often these two ends can be accomplished simultaneously by using an emetic in a large quantity of fluid. Time should not be lost in searching for an antidote; instead, any of the following substances at hand may be given in amounts ranging from 4 to 7 glassfuls: soapy water, dish water, salt water, or milk. Milk is particularly desirable if the substance taken is corrosive. If the water used is warm, vomiting will usually occur; if it does not, the back of the throat should be tickled after several glassfuls of the emetic have been taken. If the substance swallowed is corrosive, milk and eggs beaten together are helpful after dilution and vomiting have been effected.

If the poisoning is by sleep-producing drugs, an effort should be made to keep the patient awake. Strong coffee is useful. If breathing stops, artificial respiration should be performed. In strychnine poison-

ing no stimulants should be given and the patient should be kept as quiet as possible.

Drug Addiction.

Certain alkaloidal drugs, notably morphine, heroin, cocaine and cannabis indica[1]—all deadly poisons in large doses—are habit-forming if used frequently. These drugs administered in small amounts occasionally by a physician lead to no ill effects; indeed, morphine used to relieve suffering and anxiety is one of the most valuable medicaments. The physician is cautious, however, not to repeat the dose too frequently because of the danger of habituation, although actually there is little danger of psychologically normal individuals thus acquiring the habit. It occurs mainly among those who are chronically "tired." There is nothing more tragic than the unfortunate victim of a drug addiction, and the law wisely prohibits the sale of these drugs to anyone except physicians. There is, nevertheless, an illicit traffic by which the addicts obtain their narcotics, but at exorbitant prices.

Drug addiction usually occurs as the result of the desire to obtain escape from an unpleasant situation—often a personality difficulty—or to obtain a stimulation that gives bravery and destroys fear. Often young people are initiated into the drug habit by unscrupulous older companions, sometimes those whose sole desire is to create a market for the drugs they sell.

When first used, the narcotic drugs give a feeling of security, exhilaration and freedom from fatigue. As the effects of the drug wear off, irritability, insomnia and discomfort develop. These after-effects become more marked as the use is continued, until finally they are so severe that the drug must be taken to relieve them. The addict thus imposes upon himself a suffering that requires a continual use of the drug to avoid the agonizing consequences of withdrawal. With use, toleration to the drug is developed, and more and more must be taken to obtain relief. To a person unhabituated to morphine 1/6 grain of the drug is a medicinal dose and ½ grain might produce severe poisoning; on the other hand, the addict may require from 10 to 50 grains a day to relieve his discomfort.

Usually the adverse physical symptoms of drug addiction develop

[1] Indian hemp, also known as hashish and marijuana. Cigarettes containing this drug have been sold under the names "Muggles" and "Reefers." It is said to be used, but with eventual deleterious effects, by some musicians because of the distortion of time perception it induces.

within six months. The skin becomes sallow; weight is lost; the teeth decay rapidly; the breath is foul; there is extreme constipation. Along with or preceding the physical changes there are definite psychological alterations. The addict becomes selfish and self-centered; responsibilities are ignored and promises broken. Sleep is poor and is broken with nightmares.

The cure of drug addiction is difficult. Under proper medical care the addict can be restored to good physical condition and freed from the craving caused by the withdrawal of the drug. He is then physically and mentally much in the same position he was before he started to use drugs. Unfortunately, he generally has the same psychological maladjustments and temptations as before. He frequently returns to his habit. The problem of drug addiction is more a matter of psychology and sociology than of medicine.

Alcoholism.

There are many different kinds of alcohols; the one used as a beverage is ethyl alcohol. Pharmacologically this alcohol belongs to the group of anesthetics. It is a depressant. The apparent exhilaration that results from its use arises from release from psychological inhibitions. Restraints developed in character by training and education are destroyed by alcohol; the timid become brave, and the brave, reckless. Alcohol is used as a bolster to conviviality by those who feel that they lack this quality; it is also used as an escape from an undesirable environment, from reality, and from the personality abnormalities of the individual that conflict with social standards. The use of alcohol in intoxicating quantities unquestionably contributes to sexual immorality, not because it excites sexual desire, but because it destroys inhibitions. It thus secondarily contributes to the spread of the venereal diseases. Although the moderate use of alcohol does not lead to immediate habituation in the sense that the use of the narcotic drugs does, nevertheless many individuals in time become dependent upon alcohol; they become chronic alcoholics.

Alcohol is rarely ingested in full strength or pure; the alcoholic beverages contain, in addition to various percentages of alcohol, water, flavoring matter and other ingredients. Beer and ale are made from fermented cereals without distillation; they contain from 3 to 6 per cent of alcohol by volume. Wines are made from fermented grapes and are sometimes "fortified" by the addition of distilled spirits; they

contain from 6 to 22 per cent of alcohol. Liqueurs and cordials are concocted by adding syrup, fruit and spices to alcohol. Whiskey is made by distilling the alcohol from various carbohydrate substances—corn, rye, potatoes—and aging the distillate in charred oak kegs; it contains 40 to 50 per cent of alcohol.

When an alcoholic beverage is ingested, the alcohol is rapidly absorbed into the blood and is carried to every part of the body. The resultant physiological effects arise from the action of the alcohol upon the brain. They are determined by the concentration of alcohol in the blood reaching the brain. The correlation between concentration in the blood and physiological effects is given in Table X. Here also is given the quantity of alcohol which must be ingested within a short time to produce these effects. The values are approximate only, and subject to individual variations; they are for absorption from an empty stomach. When alcohol is taken on a full stomach absorption is slower and larger quantities are required to reach the concentrations given. Furthermore, the values are calculated for a man weighing 157 pounds; for smaller or larger individuals the volumes should be altered correspondingly.

TABLE X.—CORRELATION BETWEEN CONCENTRATION OF ALCOHOL IN BLOOD AND PHYSIOLOGICAL EFFECTS

Concentration of Alcohol in Blood. Mg. Alcohol per c.c. Blood	Physiological Effects	Approximate Volumes of Pure Alcohol Taken in Short Time on Empty Stomach Necessary to Obtain Concentration Given[a]
0.5	Barely appreciable feeling. Ordinarily no noticeable effects.	1 oz.
1.0	First signs of mild intoxication. Automobile driving dangerous.	2 oz.[b]
2.0	Unmistakably drunk.	4 oz.
4.0 to 5.0	Deeply drunk, unconscious.	8 to 10 oz.
8.0 to 9.0	Respiratory failure and death.	16 to 18 oz.

[a] Subject to qualifications given in text. The alcohol from beer is absorbed much more slowly than that from distilled spirits, such as whiskey, and particularly gin, from which the alcohol is absorbed with special rapidity.

[b] This amount of alcohol is that in 4 ounces of whiskey or gin or 2 quarts of beer.

After alcohol is absorbed into the body the major portion, some 90 per cent, is slowly oxidized; the remainder is eliminated largely through the breath and urine. The rate at which alcohol is oxidized is influenced by constituents, still unknown, in the various beverages. The alcohol of some, therefore, stays in the body longer than others, with corresponding degree of after-effect. From six to forty-eight hours are required to rid the body of alcohol, depending upon the amount drunk and the nature of the beverage. The ill effects of the recovery period, the so-called "hangover," are of essentially the same nature as the ill effects experienced from inhalational anesthetics such as ether used for surgical operations. The greater the amount and the longer the alcohol persists, the more severe the after-effects. The higher alcohols, such as fusel oil, present in distilled spirits contribute little or nothing to the after-effects. Methyl alcohol, sometimes a constituent of denatured alcohol, but never of legal beverage alcohols, is not oxidized in the body; it is an accumulative poison.

The consumption of large quantities of alcohol daily results eventually in definite bodily disturbances. In part these disturbances are not from alcohol poisoning but from dietary deficiencies, as discussed in Chapter V.

In chronic alcoholism will power and self-respect deteriorate, and an attitude of self-pity frequently dominates behavior. Occasionally acute effects of the condition occur as delirium tremens. Excitement, physical injury, and infectious diseases are often precipitating factors to this disturbance. It most often occurs after a prolonged spree and is frequently complicated by extreme dietary deficiency. Excitement, fear, and hallucinations develop. The disease is serious; it has a considerable mortality. A modified and milder form of the disturbance called alcoholic hallucinosis may follow a prolonged spree. In this there are intense fear and hallucinations, but of hearing rather than of sight. Recovery usually occurs.

The action of alcohol on the body is strictly a matter of physiology, but this science goes no further than the statement of physiological facts. Physiologically there are no beneficial, but only harmful, effects from the use of alcohol; that is, no bodily function is improved by the presence of alcohol, and when taken in sufficient quantities, some are definitely harmed. It is improbable that the moderate use of alcohol seriously harms health; the excessive use does without doubt. Any advantages that may be found in the use of alcohol must lie in its psychological effects in temporary freedom from worry, fears, and re-

pressions. But here the advantages must also be weighed against the disadvantages, and the question decided by the psychologist and psychiatrist. The social and ethical aspects of alcoholic indulgence belong to the fields of sociology and religion. And there is no unanimity in the sociological regard of indulgence; discussions of the subject are often dictated by desire and emotion rather than scientific fact. Consequently there are wide differences of opinion, particularly in regard to so-called moderate indulgence. Many men remain moderate users of alcohol, but it must be remembered that all chronic alcoholics were at one time moderate users.

Tobacco, Coffee and Tea.

The use of tobacco, coffee and tea leads neither to the extreme habituation nor to the serious consequences that follow that of narcotic drugs. Nevertheless, their use depends upon drug action—nicotine in the case of tobacco, and caffeine in that of coffee and tea.

The only pharmacologically active ingredient in tobacco smoke is nicotine. This drug is present in all tobacco, but varies with the sorts in amounts ranging from 0.5 to 6.0 per cent. Nicotine is burned and destroyed at the point of combustion in the cigar, pipe or cigarette, but the drug present near this area is volatilized by the heat and distilled into the stream of air drawn through the tobacco. The amount thus volatilized depends upon the manner in which the tobacco is burned; it is greatest for cigars, less for pipes and least for cigarettes. From 10 to 33 per cent of the nicotine in the tobacco reaches the smoke; approximately half of this is absorbed if the smoke is not inhaled, slightly more if it is inhaled.

Nicotine affects the nervous system, first stimulating and then depressing it. Its action on the vomiting center is particularly striking; the first experience with tobacco frequently leads to nausea and vomiting. Habituation diminishes the effect of nicotine on the vomiting center, but the habituated heavy smoker usually unconsciously regulates his smoking to a point just below nausea. Habituation does not apparently diminish the action of nicotine on the conducting system of the heart.

No figure can be given for the amount of tobacco that constitutes excessive use, for there is toward nicotine an enormous individual difference in susceptibility. Some smokers experience palpitation and irregularity of the heart, shortness of breath and nervousness from an amount of tobacco that has no appreciable effect on other smokers.

There are no serious withdrawal effects when smoking is stopped. It is, however, difficult for the heavy smoker to "taper off" and maintain a more moderate use of tobacco; abrupt cessation is the only satisfactory way of breaking the habit.

Caffeine (and often theophylline, which has a somewhat similar action) occurs in many plants; it is commonly taken as a decoction from the roasted coffee bean and dried tea or maté leaves. A cup of coffee as ordinarily brewed yields from 2 to 3 grains of caffeine; and a cup of tea contains a like amount and in addition about 1 grain of theophylline. Cocoa has no caffeine, but does yield a small amount of theobromine which is similar to theophylline.

Caffeine may be called a "brain stimulant"; it quickens the thought process and gives increased sensory perception; it "wakes up" the individual who takes it. It also increases the flow of urine. Its excessive use is followed by nervousness and insomnia; in some cases by extreme restlessness. There is apparently little toleration developed for caffeine; some individuals are able to withstand large amounts, while others feel restless and nervous after comparatively small amounts.

CHAPTER XI

THE URINARY SYSTEM AND ITS DISORDERS

THE VITAL ACTIVITY OF PROTOPLASM, THE UTILIZATION OF ENERGY FROM food material, in fact, all the processes of the body, result in waste substances or end products which must then be eliminated from the body. During the combustion of carbohydrates and fats, carbon dioxide is formed. The combustion of proteins produces, in addition to this end product, urea and the salts of sulphuric and phosphoric acid. The respiratory system and the urinary system are the main excretory organs through which these substances are eliminated. The eliminative functions of the lungs and of the kidneys are complementary. The lungs are the channel of egress for gaseous substances; the kidneys are the channel of egress for solid substances in solution. Carbon dioxide and some water are eliminated through the lungs; urea, water, and inorganic salts are eliminated through the kidneys.

In addition to the two main excretory systems, there are also two minor excretory systems—the skin and the alimentary tract. The skin assists the excretory activities of the kidneys, for sweat carries in solution solid wastes. This excretion of wastes through the skin is, however, a minor function in comparison with the skin's activity in dissipating the heat generated in the body. The alimentary tract is the channel of egress for a small amount of inorganic salts such as iron and calcium. The fecal matter, aside from these additions, is not a waste product. It is detritus—material in the food which is not digestible, and bacteria which have grown in the intestines.

Elimination Through the Kidneys.

The substances eliminated through the urinary system come directly from the blood which flows through the kidneys. The kidneys exercise both a selective and a regulatory activity in respect to these substances. Thus urea is selected from among the constituents of the blood and is removed as completely as possible. Other substances which are necessary to the functioning of the body and are normal constituents of the blood, are eliminated through the urine only when they exceed in

amount some definite normal concentration. Elimination through the kidneys thus not only serves to remove true waste, but also plays a large part in maintaining uniform concentrations of the normal constituents of the blood.

The elimination of sugar (dextrose) through the kidneys in diabetes is an example of this regulatory activity. Normally there is no appreciable amount of sugar in the urine; but when the concentration of sugar in the blood exceeds the normal upper limit, about 0.18 of one per cent, the excess tends to pass into the urine. The concentration of sugar in the blood is thus prevented from rising excessively (see Chapter IV). The excretion of acid and basic materials through the kidneys, similarly regulated, assists in maintaining the normal balance of alkali and acid in the blood. This balance is an essential part of the regulation of breathing to the rate of carbon dioxide production (see Chapter VIII).

The regulation of the excretion of alkaline and acid substances by the kidneys is shown in the variations in the reaction of the urine. The urine may be either alkaline or acid, depending upon the nature of the diet. When the diet is composed largely of vegetables, the urine is alkaline, for vegetables contain an abundance of alkaline salts. This is the case even with acid fruits, for the organic acids such as citric and tartaric acid are oxidized to carbonates in the body. From a meat diet an acid urine results, for the combustion of protein produces an excess of inorganic acids such as sulphuric and phosphoric, which are eliminated through the urine. This is usually the case also from a mixed diet; and it is always the case in starvation.

Structure of the Urinary System.

The urinary system consists of the kidneys, ureters, bladder, and urethra. The kidneys are large glands in which water and solids in solution are separated from the blood. The urine thus formed is conveyed by the ureters to the bladder. The bladder is a distensible receptacle in which the urine is temporarily stored. The urethra is the passage through which the urine is discharged when the sphincter of the bladder is relaxed.

The Kidneys.

The kidneys are placed one on each side of the spinal column and rest upon the muscles of the back or loins. The lowest ribs are ap-

proximately on a line with the middle of the kidneys. The kidneys are shaped like beans. The depressed portion of each, corresponding to the point at which the bean is attached to the pod, faces toward the spine. It is at this point that the blood vessels and ureter join the kidney.

The kidney of an adult weighs from 120 to 150 grams (about one-quarter pound); it is of a brownish red color, and is covered by a

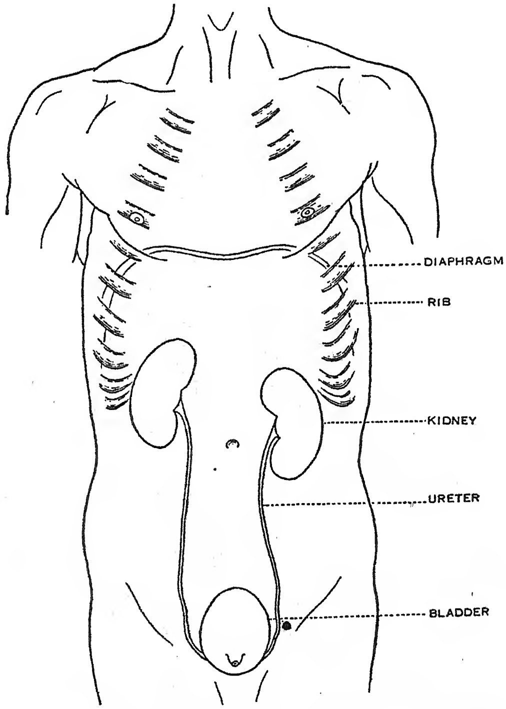


Figure 42. Position of Kidneys, Ureters, and Bladder.

firm capsule of connective tissue. The small adrenal glands are placed just above the kidneys and these, together with the kidneys, are surrounded with fat. The kidneys are supported in place by layers of connective tissue which run along the back, but there are no bands or membranes attached to the capsules to hold them firmly in position. Occasionally one of the kidneys, usually the right, becomes loose and movable, a condition called "floating kidney." As a rule, no disturbance results unless the ureter becomes kinked or compressed, in which

case the urine is dammed back in the kidney and upper end of the ureter. The distention of these structures gives rise to severe pain.

The ureter widens out like a funnel at the point of attachment to the kidney. A space is hollowed out inside the kidney to accommodate this widened end. A great number of minute tubes open into this space. These tubules radiate toward the surface of the kidney. At their outer ends they are widened and convoluted; at the tip of each is a minute bulb, the glomerulus, surrounding a coil of small blood vessels.

Secretion of Urine.

The secretion of urine involves three phases in the activity of the kidney. Water and dissolved substances in the blood are first filtered

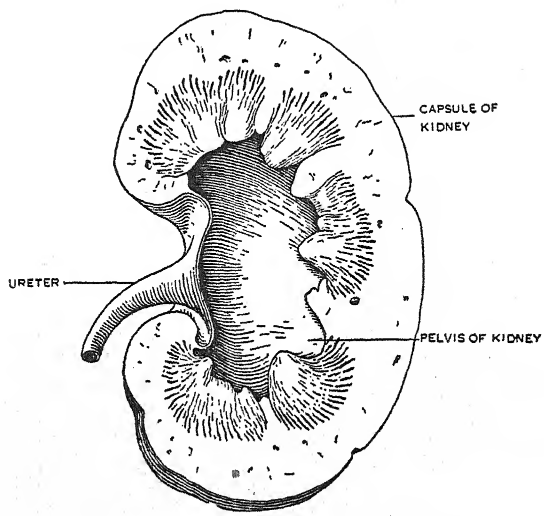


Figure 43. Longitudinal Section of Kidney.

off. From this filtrate a considerable portion of the dissolved substances and part of the water are reabsorbed into the blood. At the same time additional waste materials are secreted from the blood into the concentrated filtrate.

The primary filtration of water and solids occurs in the bulbs or glomeruli at the end of the kidney tubules. Fluid exudes through the walls of the capillaries of the glomeruli as it does from all other capillaries in the body, as described in connection with lymph formation. Protein does not normally pass through the walls of the capillaries.

The fluid received by the bulbs from the capillaries is water containing salts, sugar, urea, amino acids, and all the other soluble constituents of the blood. It is necessary to pass a large amount of fluid in order to carry away the waste materials from the blood by the process of simple filtration. In addition, the filtrate contains a certain amount of foodstuffs, such as sugar and salts, needed for the maintenance of the body. These useful materials are salvaged by reabsorption from the filtrate as it passes through the first portion of the tubules leading from the glomeruli.

In addition to the selective absorption of water, salts, and sugar, it is probable that the kidney tubules also actively secrete material into the concentrated filtrate. The cells along the tubes are probably able to secrete urea and similar waste substances, and thus to reduce the concentration of these substances in the blood to a lower level than could be accomplished by filtration alone. In animals living on land a large part of the water is also absorbed from the filtrate, so that the volume of urine voided is much less than the amount of fluid filtered off from the blood in the glomeruli. The urine, therefore, may have a higher specific gravity than the blood. In aquatic and amphibian forms of life this saving of water is not essential; a frog passes his weight or more of urine each day. In birds a further saving of water is brought about by emptying the urine into the lower part of the large intestine, where the water is absorbed, so that the bird's urine is a whitish paste.

Rate of Secretion.

Usually from 40 to 60 per cent of the total amount of fluid taken into the body is eliminated through the kidneys. The quantity of urine secreted in twenty-four hours by a healthy adult under ordinary circumstances is from one to two quarts, but these values are subject to wide variation. The minimal quantity of fluid necessary to carry away the waste in solution is comparatively small. The lowest level of secretion occurs during exertion in hot surroundings; under such circumstances the loss of water through the skin is incompletely compensated by the amount of water drunk, and the concentration of the urine is indicated by its dark color. On the other hand, the quantity of urine may be increased to eight or ten quarts a day by drinking excessive quantities of fluid or from disturbances in the water regulation of the body.

The rate of secretion of urine is influenced mainly by three factors: (1) the supply of water in the body, (2) the volume or pressure of the

blood passing through the kidneys, and (3) the activity of the secretory and absorptive processes in the kidneys. The rate of secretion increases as the supply of water in the body rises from the ingestion of fluid, and diminishes as the supply of water falls as a result of the loss through the kidneys, through the skin as sweat, or from the digestive tract, as in diarrhea. The secretion of urine is also increased when the rate of the blood flow through the kidneys is augmented. Thus the rise in arterial pressure caused by mental concentration, worry, or anxiety increases the rate at which urine is formed. Chilling of the skin

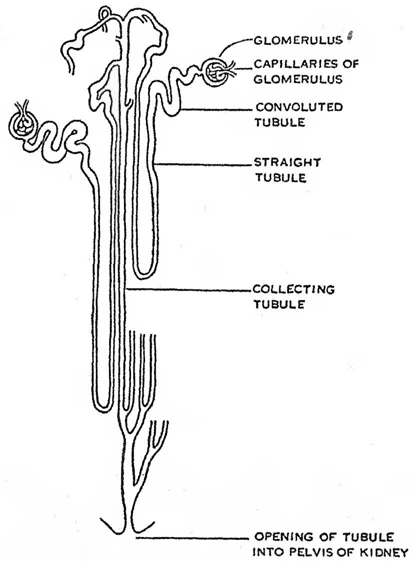


Figure 44. SCHEMA OF URINARY TUBULE AND GLOMERULUS.

also increases the flow of blood to the kidneys, and hence the volume of urine. Some substances, notably caffeine of coffee and theophylline of tea, increase the rate of urine formation. These substances are called diuretics. They act by increasing the flow of blood to the kidneys or by stimulating directly the secretory activity.

In diabetes mellitus, uncontrolled by insulin, and in diabetes insipidus, caused by a disturbance in the pituitary gland, the volume of urine is greatly increased. It is also increased, especially at night, in a type of chronic kidney disease or nephritis, which is especially prone to affect the aged. Normally the amount of urine secreted during the day is two to four times as great as that secreted at night. This relation

is reversed in individuals who work at night and sleep during the day. The flow of urine is diminished in fevers, in heart failure and in certain types of kidney disease. Young children excrete three to four times as much urine for their weight as do adults.

The Ureters, Bladder and Urethra.

The ureters are slender tubes 25 to 30 centimeters (10 to 12 inches) long, one of which extends from each kidney to the bladder. The urine is carried through the ureters in drops by a movement of the walls analogous to that which carries the food through the esophagus and intestines.

The bladder is a reservoir for the collection of urine. The flow of urine from the kidneys is practically continuous, although the volume varies. The bladder collects this flow and allows the ejection of the accumulation at convenient intervals, an advantage similar to that afforded by the stomach in the taking of food and by the large intestine in the ejection of the feces.

The bladder lies beneath the peritoneum of the lower part of the abdominal cavity near the front wall. The ureters and urethra open into it on its under surface. This part of the bladder is held firmly in place by ligaments; the unattached upper side is the distensible portion. (See Figure 42.)

The size of the bladder depends upon the volume of its contents. Its capacity is variable. The point of distention which ordinarily induces a persistent desire for evacuation is determined by the habits of the individual. The figures for this capacity range from 180 to 720 cubic centimeters (6 to 24 ounces), with about 500 cubic centimeters (1 pint) as an average. The bladder is stretched, and its capacity greatly increased, by habitually allowing a large amount of fluid to accumulate before evacuation. Under abnormal conditions the bladder may be forced to hold three or four liters.

The urethra, which is the canal conveying the urine from the bladder to the exterior of the body, is about one and one-half inches long in the female, and much longer in the male. In the male it is modified to function as a part of the sexual apparatus.

Evacuation of the Bladder, Micturition.

The flow of urine through the urethra is controlled by two muscular valves. The first of these valves is formed by a thickening of the muscular wall of the bladder surrounding the opening into the urethra;

the second valve is a separate muscle which encircles the urethra after it has left the bladder. The first valve is controlled by an automatic or reflex mechanism and is not under voluntary control. When the bladder has filled to a certain degree, or rather to a certain pressure, this valve opens and allows some urine to enter the urethra. This passage of the urine into the first part of the urethra gives rise to a conscious desire to urinate. If no obstacle is presented the bladder empties itself by the contraction of its muscular walls. The emptying of the bladder may be prevented by the second muscular valve about the urethra which is under the control of the will. This control, as in the case of that over the anal sphincter in defecation, is obtained by training in infancy. It may be lost during unconsciousness; the urine is then voided involuntarily.

The pressure in the bladder which initiates the reflex part of micturition is influenced by two factors: the volume of urine collected and the tenseness of the walls of the bladder. The bladder is a muscular organ and its tenseness is varied by the activity of the nervous system. The bladder is made more tense by excitement or anxiety; as a result, the desire to micturate arises even when only a small amount of fluid has collected. If the micturition is prevented by the action of the valve which is under voluntary control, the bladder may subsequently relax, and as it relaxes the involuntary valve closes. The desire to micturate then passes off until the fluid has collected in further quantity sufficient to raise the pressure.

Irritation of the urethra or of the bladder near the urethral opening gives rise to the desire to micturate even though the bladder is not distended. Irritant condiments such as ginger, mustard, or pepper, of which the essential oils are eliminated through the urine, may irritate the bladder. The irritation may also arise from bacterial infection in the bladder. The infection enters either by way of the kidneys or as an ascending infection from the urethra. Inflammation of the bladder is known as cystitis.

Enlargement of the prostate gland, a stone in the bladder, or a stricture of the urethra may prevent the bladder from emptying. The prostate gland is an accessory organ of the male generative apparatus. The urethra passes through the substance of this gland. The gland often enlarges in old men, compresses the urethra, and thus obstructs the flow of urine. It is then necessary to pass a metal, rubber, or enameled linen tube, called a catheter, through the urethra to withdraw the

urine. The continual use of the catheter is annoying and frequently leads to cystitis. The obstruction can be relieved by removing the prostate gland by surgical operation.

Stone in the Bladder.

Stones sometimes form in the bladder; they are usually composed of the salts of uric acid and of the oxalate and phosphate of calcium. In some instances the stone forms as an incrustation on a foreign substance in the bladder, a blood clot, a clump of bacteria, or objects introduced from the outside. More often the stone is formed entirely of material precipitated from the urine. The factors predisposing to this precipitation are unknown; the fact that the condition is more prevalent in some countries than in others suggests a dietary factor, possibly a vitamin deficiency. The stone often forms in the upper end of a ureter, and in passing down to the bladder gives rise to intense pain like that of gallstones. The stone thus formed may be very small, in which case it is passed in the urine as "gravel"; or it may lodge in the bladder and grow to a large size by the deposit of material on its surface. Ultimately the stone irritates the bladder or obstructs the flow of urine. Stones are removed from the bladder by surgical operation; either the bladder is opened or the stone is crushed by a clamp-like instrument passed through the urethra. "Cutting for the stone" is a very ancient surgical operation.

Stricture.

The walls of the urethra are ordinarily in apposition; the flow of urine spreads the walls apart and forms a canal. A stricture prevents dilatation and so obstructs the flow of urine. In acute gonorrhea the mucous membrane of the urethra may become swollen to such an extent as to cause stricture. Or, as a result of the healing of the disease the walls of the urethra may be scarred and hardened, so that they dilate to only a limited extent. The partial obstruction caused by scarring may become complete for a time as a result of exposure to wet or cold, especially after drinking alcohol. A blow on the urethra, or trauma from riding on horseback, may cause a temporary stricture even in men who have had no previous inflammation of the canal. Such temporary stricture may usually be relieved by a hot bath and emptying the bowels; otherwise it is necessary to pass a catheter to remove the urine which has collected.

Suppression of Urine.

The secretion of urine may cease as a result of disease. Obstruction of the ureters by stones or tumors results in such a suppression; more often the obstruction occurs in only one ureter and the opposite kidney carries on the functions of both. In severe injury to the kidney from poisoning by bichloride of mercury the flow of urine may be stopped entirely. The usual duration of life after complete suppression of the flow is from a week to ten days. At first there is no particular illness, but after a few days headache and weakness develop, and finally unconsciousness and death. In these cases death is due to uremia or, as it is sometimes called, uremic poisoning.

Albumin in the Urine.

Protein does not pass through the walls of the capillaries surrounding the renal tubules and therefore does not normally appear in the urine. Under certain circumstances, however, protein or, as it is usually called, albumin finds its way into the urine. The appearance of albumin always arouses a suspicion of disease in the kidneys. Nevertheless, albumin may appear, even when the kidneys are normal, after violent muscular exertion, such as a rowing race, football game, or a long-distance running contest. Ordinarily the passage of albumin ceases after a day or two, but in some instances it may continue for a week, and, in exceptional cases, even longer. Albumin may also appear in the urine after prolonged exposure to cold. It sometimes appears in the urine of young people, but usually it is passed only during the time they are standing; hence it is found in the urine secreted during the day, but not in that secreted at night. The positional effect does not arise from any defect of the kidneys; it is often associated with improper standing posture in which the lower part of the back is curved forward to an exaggerated degree. The albumin usually disappears from the urine when adult years are reached; and in some cases it may be stopped earlier by correcting the posture.

In disease of the kidneys the albumin may appear not only in the dissolved form, but also as solid particles which are visible under the microscope. These bits of protein material are shaped like the inside of the urinary tubules in which they are formed; for that reason they are known as "casts."

Albumin in the urine cannot be detected by mere inspection; a chemical test is necessary. Neither cloudiness of the urine nor formation of sediment after the urine has stood are indications of albumin.

Such sediments are usually phosphates or oxalates which readily precipitate out of the urine. These precipitates are not significant of disease, although the literature of some patent medicines implies that these perfectly normal precipitates are grave indications of disease which are, of course, "curable" by the patent medicine.

Blood in the Urine.

When blood, or the products of disintegrated hemoglobin, appear in the urine, it is colored either dark red or a smoky black. Like albumin, blood in the urine is not always a sign of disease in the kidneys. Occasionally the kidneys bleed, just as the nose does, from no apparent cause. A severe blow over the back may likewise cause bleeding from the kidneys. Blood may appear in the urine as a result of inflammation in the urinary passages arising from infection, or from the irritation due to stones. When the red blood corpuscles are disintegrated in large amounts by disease or poison, the liberated hemoglobin is excreted through the kidneys and appears in the urine as in "black-water fever," a severe form of malaria. Finally, blood may appear in the urine as a result of inflammation of the kidneys, nephritis; it is then of very serious significance.

Acute Nephritis.

The term nephritis as commonly used covers a variety of diseases of the kidney. The conditions, sometimes acute and sometimes chronic, are frequently called Bright's disease. None results from direct infection of the kidney, i.e., such as tuberculosis of the kidney, but instead from injury by substances which irritate the kidneys or which disturb their circulation.

So-called acute nephritis usually occurs before the age of forty. It results most commonly from the action of the toxin formed during scarlet fever, streptococcus tonsillitis, and diphtheria. It may result from the absorption of toxic materials from extensive burns, and also from such poisons as bichloride of mercury, turpentine and Spanish fly. Severe exposure to cold and wet may be followed by acute nephritis. The chilling of the skin acts upon the circulation of the kidneys. Even a mild degree of chilling is followed by an increase in the flow of urine because of the increased blood supply; in severe chilling the kidneys are damaged by the congestion which results.

Pregnancy is occasionally complicated by the development of acute nephritis. It occurs in women whose kidneys are not able to support

the burden added to the excretory system by the pregnancy. Frequent examination of the urine during pregnancy is important, for the appearance of albumin is a warning of the failure of the kidneys; it is still more important as an indication of the development of another condition known as eclampsia, which is even more serious in pregnancy than is nephritis. Although eclampsia is not primarily a disease of the kidneys, its presence is usually preceded by the appearance of albumin in the urine. (See page 512.)

In acute nephritis the urine may be entirely suppressed, but more commonly it is scanty and highly colored, and contains blood and albumin. Only four or five ounces of urine may be passed in twenty-four hours. The damage to the kidney may be followed by dropsy, which is shown in swelling of the ankles and eyelids, and by anemia, which gives to the skin a peculiar waxy pallor.

In those cases of bichloride of mercury poisoning in which death occurs about two weeks after the ingestion of the poison, the fatality results from the damage to the kidneys. Although the immediate action of the bichloride upon the digestive tract is acutely painful, the subsequent inflammation of the kidneys is not. The mistaken belief that bichloride poisoning results in painless death led at one time to a vogue for this poison as a means of suicide. A more unpleasant poison could hardly be found unless it were its predecessor in favor, the equally corrosive carbolic acid.

In severe cases of nephritis from any cause death may result from uremia; more often, however, there is recovery, sometimes complete, sometimes partial. The urine then gradually returns to a normal amount and the albumin disappears. In some cases the damage to the kidneys remains permanently and the disease becomes chronic.

Chronic Nephritis.

There are two main sorts of chronic nephritis. One is a sequel to acute nephritis; the other results from arteriosclerosis of the vessels of the kidneys. The second variety rarely occurs before fifty years of age; after sixty, however, it becomes a common disease. Sometimes in chronic nephritis following the acute condition in early life there is swelling of the eyelids, a sallow complexion and anemia. More often, however, and always in the arteriosclerotic variety, the outstanding symptoms are from the circulatory system.

The impaired circulation to the kidneys results in a rise in arterial pressure. This rise in turn leads to hardening of the arteries and strain

upon the heart. Uremia may be a cause of death; more commonly it results from failure of the heart or from some consequence of the arteriosclerosis. The amount of urine secreted is usually increased in chronic nephritis, especially at night. There is usually some albumin present, but ordinarily only small amounts.

Chronic nephritis is incurable; the anatomical condition upon which it depends is as much beyond the reach of treatment as are gray hair and wrinkles. The condition is, however, compatible with the enjoyment of life for many years. The combination of symptoms common in men past middle age—increased arterial pressure, hardened arteries, and increased flow of urine—does not lead to immediate death, nor does it necessarily interfere with the pursuit of an active life as long as proper care is taken. Such care consists of moderate and regular exercise, avoidance of overeating, particularly of meat, freedom from worry and, if possible, residence in an equable climate.

After middle age the yearly medical examination has as its main object the early discovery of the changes in the circulatory system and kidneys which indicate the development of chronic nephritis and arteriosclerosis. Although the damage cannot be remedied, its progress can be retarded; for this reason the early detection of the condition is important.

CHAPTER XII

THE SKIN AND ITS INFECTIONS

THE SKIN SERVES TWO IMPORTANT FUNCTIONS: (1) PROTECTING THE UNDERlying tissue; and (2) dissipating the heat produced in the body. If the loss of heat is prevented over the entire skin area, an intense fever develops and death follows in a short time. The process of heat dissipation from the skin is regulated by the nervous system, which controls the activity of the blood vessels and sweat glands in the skin so that a nearly uniform body temperature is maintained. (See Chapter XVIII.) The skin is impermeable to water and thus prevents the body from drying up, as it would if the unprotected tissues were exposed to the air. The same waterproof characteristic prevents the passage into the body of substances applied to the skin; many chemicals dissolved in water are rapidly absorbed into the blood if they are applied to areas from which the skin has been removed. Even more important is the fact that if it is unbroken, the skin prevents the entrance of most of the vast hosts of bacteria which constantly come in contact with it. The skin is the organ of the body most intimately in contact with the environment; it is the one most exposed to injuries and infections.

Structure of the Skin.

The deepest layer of the skin consists of a sheet of connective tissue to which are confined all of the nerves, blood vessels, and lymphatics of the skin. This layer, called the corium, serves to nourish the layer of epithelial cells which rests upon it. The area of corium in contact with the epithelial cells is increased by its irregular contour. It rises in small hills or papillae which project into the epithelial layer. Ridges of the papillae form the small lines seen on the palms of the hands and on the fingers; they yield the finger prints. The under surface of the corium is infiltrated with fat, upon a layer of which substance the skin rests. The corium is the layer of the skin which, when tanned, forms leather.

Several layers of epithelial cells rest upon the corium. By gently

scratching the skin with a pin a very appreciable furrow may be made before the lymph or blood from the corium appears, thus showing the absence of these fluids in the epithelial layers.

The layer of epithelial cells in immediate contact with the corium and nearest to the supply of nourishment, grows actively and continually produces new cells. As these cells are pushed outward by this growth, their shape and composition are gradually altered. They are flattened, and the material of which they are composed changes into a hard substance known as keratin. Keratin is the material of which are

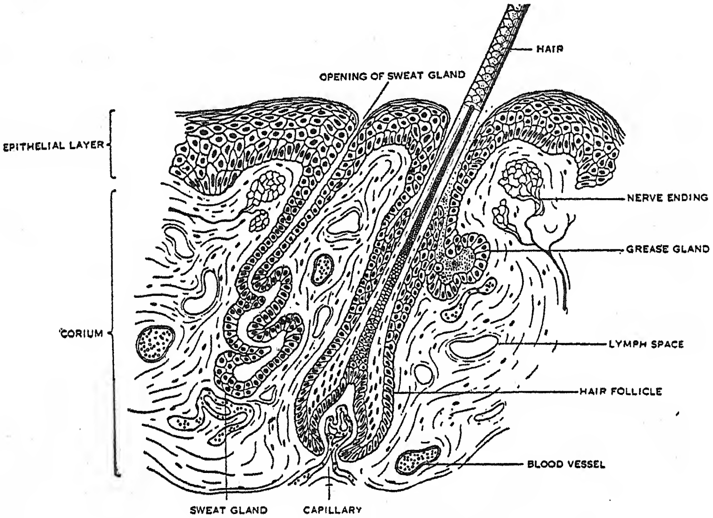


Figure 45. SECTION THROUGH SKIN.

composed not only the outer layer of the skin, but also the hairs and the finger and toe nails of man, and the horns and hoofs of other animals. The epithelial cells in which this alteration of composition has taken place are dead. They form a coating of resistant scales over the surface of the skin. These dead cells are gradually scruffed off and continually replaced by the formation and transformation of new cells.

The skin varies in thickness, being thinnest on the eyelids and thickest on the palms of the hands and soles of the feet. Unless it is tightly bound to the underlying tissue, as it is over the ears, palms, and toes, the skin is movable. It is also elastic, to which is due its smoothness in spite of temporary displacement and stretching by the movements of the joints and muscles. This smoothness is particularly conspicuous in early life. With advancing age the elasticity of the con-

nective tissue decreases, just as it does in the walls of the arteries. Folds in the skin are no longer effaced, and wrinkles are formed.

Hair.

A hair is an outgrowth of the epithelial cells of the skin. The surface of the skin is not perforated to allow the hair to emerge, but instead is depressed into a deep pit which extends into the corium or even into the fat below. The hair grows from the bottom of this pit or follicle. There a small area of actively growing epithelial cells undergoes the same transformation as the epithelial cells on the surface. Layers of dead and modified cells are piled up, forming a column which extends above the skin as a hair.

The color of the hair is determined by pigments which are in and about the cells. The color is usually, although not always, of about the same intensity as the general skin pigmentation; that is, fair-skinned people tend to have blond hair, those who are more brown-skinned have dark hair. The shape and curvature of the hair follicle determine whether a hair is straight or curly. In the case of straight hair the follicle is straight and the shaft of the hair is circular in cross section. Hairs that are wavy or curled come from follicles more or less bent and flattened or irregular in cross section.

Hair is present everywhere on the body except the palms, soles, lips, the back of the last joint of the fingers, and, in the male, the penis. There are three types of hair: (1) the long hair which occurs on the scalp, the beard area of the face, armpit, and pubic region; (2) the stiff bristles which form the eyelashes and eyebrows and which project from the nasal openings and ear canals; and (3) the downy, or lanugo, hair, which occurs on all parts of the body not occupied by the other types. The hairs are shed when they reach some definite length characteristic of the individual and of the locality on the body; they are replaced by new outgrowths of hair.

Attached to the hair follicles are small muscles under involuntary control. The pull of these muscles makes the hair stand more erect; this is an important feature in temperature control in hairy animals, but unimportant in man. In him the elevated hair follicle produces only "goose flesh." The pull of the muscle squeezes out on the surface some of the grease from the glands about the hairs.

Baldness.

Occasionally no hair appears on the body; there is complete baldness even to eyebrows and eyelashes. Much more frequently, however, bald-

ness, or alopecia, results from the loss of hair. It is far more common in men than in women. This difference is apparently due to secondary sexual characteristics that play a part not only in the loss of the hair but also in its length. It is said that in males castrated before puberty alopecia occurs no more commonly than in women. There is unquestionably an hereditary tendency to baldness; the condition is particularly associated with certain physical builds, especially the short and stocky physique.

There are a number of general diseases which may lead to loss of hair in either sex; syphilis, scarlet fever, erysipelas, typhoid fever, and smallpox are among the more common. Frequently the hair grows in after the disease has passed. Premature loss of the hair in the male is often associated with "dandruff," which results from an inflammation of the scalp; the scales that are shed are composed of grease and dead epithelial cells. As the long hairs are lost when baldness is developing, they are replaced with fine, short lanugo hair. Later this may be lost. There are a great number of treatments recommended for restoring hair; none is effective. Almost as many are recommended for preventing the loss of hair, and most are quite as ineffective. It is doubtful if clipping the hair, massaging the scalp, or subjecting it to so-called "vacuum treatments" exerts any beneficial effects; likewise none is obtained by the numerous "medicated" shampoos in which oils, eggs, and various tonics are employed. The daily use of hair oils and hair tonics yields no benefit except in supplying grease to hold the hair in place. At times grease, especially petroleum, may be harmful.

The most sensible treatment for the scalp, and likewise for the skin in other parts of the body, is to wash it with soap and water, rinse it to remove all soap, and dry it thoroughly. It is almost incredible how long some otherwise cleanly persons are willing to go without washing their scalps in the mistaken belief that cleanliness is harmful to the hair. It is not. Failure to remove the soap and failure to dry the hair may be injurious to the scalp. Cleanliness is not. Twice a week, even three times, is none too often for a shampoo for a man, for his scalp, because of his shorter hair, tends to become dirty more quickly than that of a woman. Regular washing often controls mild attacks of dandruff; severe ones need the attention of a competent dermatologist. Numerous "dandruff" germs have been found and some have been widely exploited in methods intended to remedy dandruff. It is doubtful whether infection is an important cause of either dandruff or baldness. "Germs" may be found on the dirty scalps in which dandruff occurs; they may also be removed with soap and water.

In the ordinary type of premature baldness the hair is usually lost first at the temples and the crown. There is another type of baldness, known as alopecia areata, in which the hair falls out in patches on any part of the scalp. It may occur at any time of life, even childhood. The cause is unknown but the condition may accompany nervous shocks or worry. The hair usually grows in again.

Superfluous Hair.

Superfluous hair, so-called, is not additional hair as the name suggests, but an overgrowth of hair normally present on some parts of the body. It is particularly prone to develop in moles. Following the menopause, women, especially brunettes, may develop an overgrowth of hair on the upper lip. If objectionable, hair on the face can be kept short by rubbing with pumice stone; on the legs and arms it can be removed at intervals by shaving. The numerous depilatories sold to remove superfluous hair usually consist of calcium or barium sulphide; they do no more good than shaving and may seriously irritate the skin. Hair in a mole should only be clipped short, never rubbed or treated with a depilatory. It is highly dangerous, except in the hands of the most expert roentgenologist, to attempt the removal of hair by X-ray; serious and defacing burns may follow from the inapt use of this measure. The electric needle, properly applied, permanently removes superfluous hair.

Hair may be white from birth as in the albino who is devoid of all skin pigment, or it may turn white with the passage of time. The time of whitening is largely a matter of heredity. Premature whitening has no significance of premature aging. Occasionally one or more patches of white hair appear in vivid contrast to the unaffected hair. Such partial whitening may be due to a birthmark, to a nerve injury or to leukoderma; it may also be hereditary.

Grease Glands.

There are two or more minute grease or sebaceous glands associated with each hair. In the case of the larger hair the glands open into the sac of the hair follicle near the point where the hair emerges. About the finer hairs the glands open directly on to the skin.

A sebaceous gland is formed by an irregular branching pouch that extends into the corium. The cells lining the wall of this pouch undergo a change during which they become filled with fatty material. The cells rupture, and the grease, together with the detritus from the cell,

forms the secretion. When the outlet of a sebaceous gland is blocked, as it may be by inflammation and consequent scarring over, the secretion cannot be discharged; as the growth of the epithelial cells continues, the secretion accumulates and dilates the gland. The swelling thus produced is known as a wen; when disfiguring, it can be removed by a minor surgical operation. If even a small portion of the epithelium of the glands is left, the secretion continues and the wen forms again.

Sweat Glands.

It is estimated that there are from two to three million grease glands on the surface of the body; there is approximately an equal number of sweat glands. They are not associated with hair and are especially numerous on the palms and soles where no hair occurs.

A sweat gland, like a hair follicle, is formed by an invagination or infolding of the epithelium. The long slender tube thus formed is coiled into a spiral which extends downward through the corium. The cells which line this tube do not degenerate or make a solid secretion like the sebaceous glands. They constitute a true gland like the salivary glands, and secrete a fluid which is derived from the blood in the vessels surrounding the lower portion of the gland. Perspiration only becomes evident as moisture upon the skin when the rate of secretion is in excess of the rate of evaporation into the air. The secretion of sweat is varied and is controlled by nervous action. The grease which is left by the evaporation of sweat helps to lubricate the skin. Areas which are not supplied with hair, and hence have no sebaceous glands, receive their only lubrication from the grease of the sweat. The skin of the palms and soles is relatively poorly greased, and wrinkles and whitens when soaked in hot water more rapidly than does the skin on other parts of the body. The sweat glands in the armpits, about the genital and anal regions, and about the nipples of the breast are especially large, and discharge, in addition to sweat, considerable grease and degenerated cellular material.

Sweat is normally colorless or faintly yellow. In rare instances, however, that from the axillary region may be colored red or even blue. This discoloration is due to the presence of bacteria which grow about the hairs. The sweat is stained by the colored products of the bacteria. The condition is not dangerous to health; it clears up under local treatment.

There is a wide difference in the amount of sweating in different persons under comparable conditions of exertion and heat. Since the

secretion is under the control of the nervous system the activity varies with the general nervous tone or emotional state of the individual. A person untrained in athletics usually sweats more on exertion than one who is in good physical condition; but excessive sweating is not, as is sometimes supposed, a certain sign of physical weakness. It is not increased by drinking water but may be by the use of tobacco or aspirin.

Excessive sweating is often limited to a small region, while the remainder of the body shows a normal reaction. Some persons sweat on the palms of the hands, on the feet and in the axillary regions, even when they are chilled. Excessive sweating of the feet is often associated with whitening and irritation of the skin, particularly between the toes. It greatly predisposes to the persistence of ringworm infection and permits the growth of bacteria on the softened skin. The bacteria may produce an unpleasant odor, a condition known as bromidrosis. Excessive sweating of the feet not only is annoying, but may result in incapacity for certain occupations because of the tenderness of the feet. The yielding of the plantar arches which leads to flat feet is often accompanied by excessive sweating.

There are a variety of toilet preparations intended to relieve local sweating. These are for the most part astringents such as aluminum acetate and tannic acid. As a rule, these cosmetics are not harmful when used with discretion, and they are often ineffective. In mild cases of sweating of the feet it usually suffices to wash them twice a day, to change the socks every day or oftener, and before putting them on to dust into them some mild antiseptic powder. For the more serious cases of sweating of the feet, particularly if there is bromidrosis, the advice of a dermatologist should be sought, for the remedies effective in obstinate cases can be properly applied only under his direction.

The secretion of sweat is never entirely suppressed under any circumstances. In many fevers it is markedly diminished, but profuse sweating accompanies the fall to a normal temperature. In the disease ichthyosis, a congenital malformation of the skin, the secretion of sweat is greatly diminished in the affected parts. In ichthyosis, or fish skin disease, the outer or horny layer of the skin grows excessively and becomes thick and scaly. In the milder forms of this disease the sufferer is conscious of it only in the colder months when the skin is dry and has a tendency to scaliness about the knees, elbows, and borders of the armpits. From this mild variety there are all degrees of the disease, up to the severe cases in which large areas of the body are covered by dark

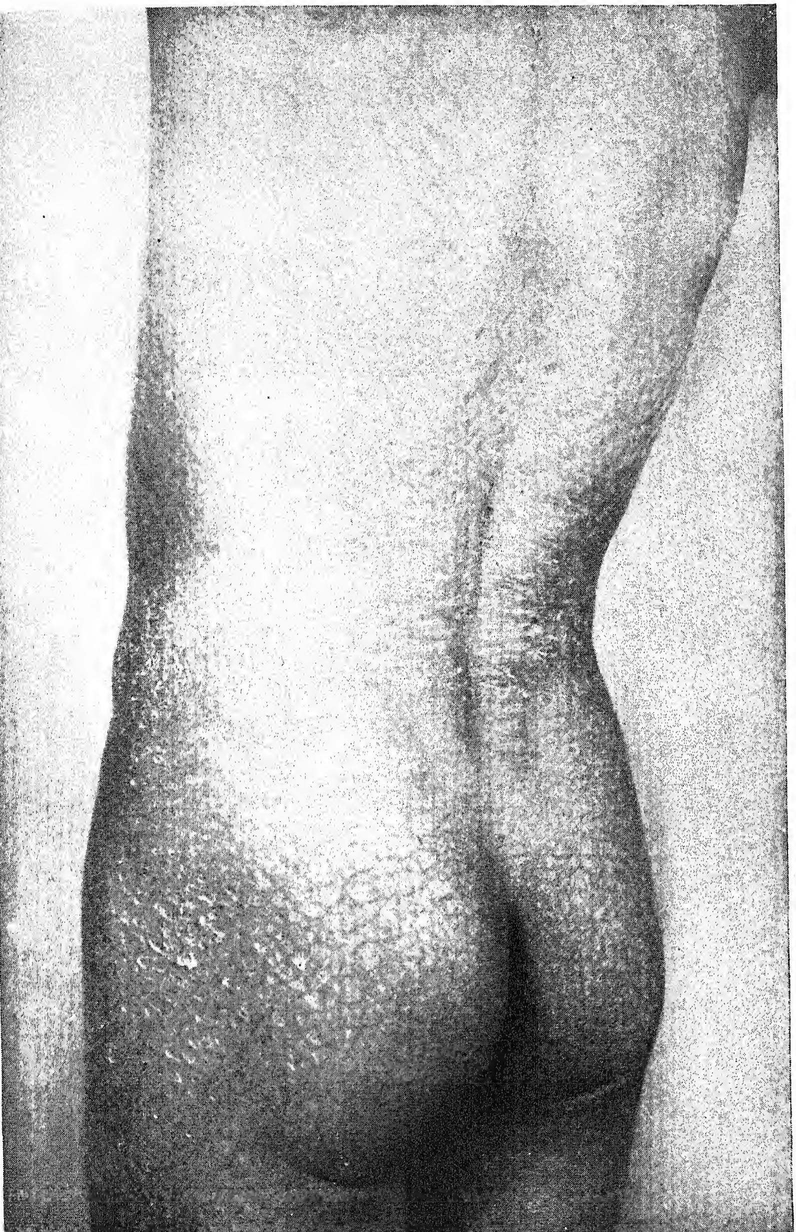
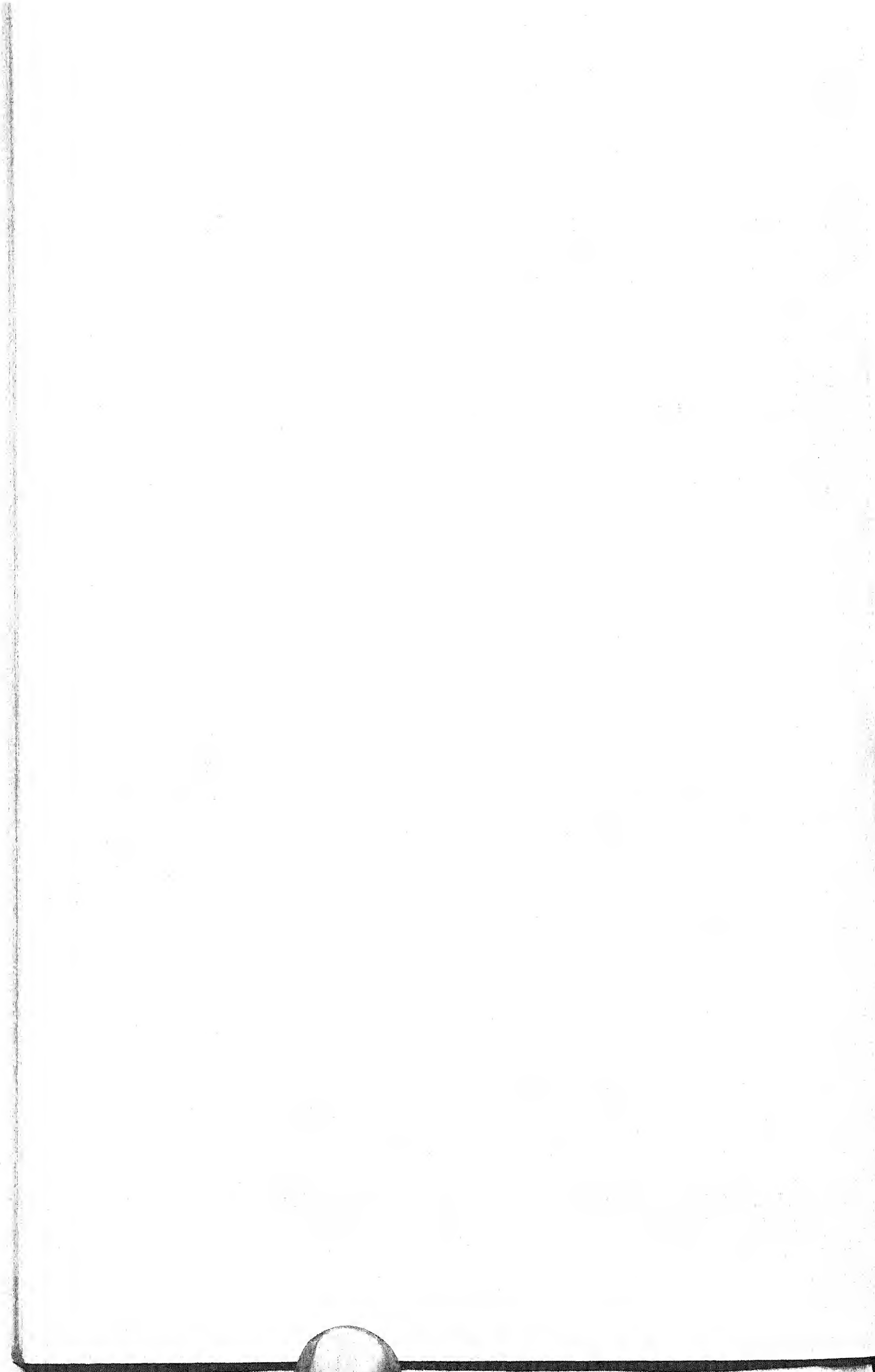

Courtesy Dr. M. Strauss

PLATE V. Ichthyosis—a fishskin disease—a congenital and permanent roughness and scaliness of the skin. See page 296.



horny masses, so that the skin resembles that of a reptile rather than that of a man.

Occasionally, especially in small children in hot weather, the sweat, possibly because of swelling of the ducts, is dammed back in the glands. Vesicles the size of pinheads are formed; they are often slightly inflamed and they itch. The condition is known as "prickly heat." Thorough washing followed by the application of alcohol and powder will usually keep the sweat ducts open.

Finger and Toe Nails.

The finger and toe nails of man correspond to the claws and hoofs of beasts. These structures are formed by the outgrowth of slightly modified horny epithelial cells. The development of a nail is much like that of a hair. At the base of the nail the skin folds back under the surface and forms a slot. This slot corresponds to the hair follicle. The epithelial cells on the lower wall of this slot form the matrix of the nail. By their growth the nail is produced. The outer limit of the matrix is marked by the white crescent or lunula, which is seen in most persons at least on the thumb, and in many on all the nails. The epithelial cells of the matrix grow and are transformed into the firm sheet of keratin of which the nail is composed.

Beyond the matrix the nail rests on the nail bed, which has no part in the growth or structure of the nail. The nail is simply pushed along the bed by the addition of substance in the matrix. The nail is held to the bed by longitudinal ridges of papillae in the nail bed, which fit into minute grooves on the under surface of the nail.

The white spots occasionally seen in the nails are due to the presence of air between the layers of cells. They have no significance, beyond indicating slight injury to the nail, frequently from manicuring. A transverse groove indicates a period of arrest in the growth of the nail and often marks the date of some illness. A longitudinal groove indicates irregular growth in the matrix and usually arises from injury of the matrix.

The nails may at times become greatly thickened, hence coarse and rough. This condition may be caused by repeated injury and by infections, particularly ringworm; it may also be a familial trait. The bed of the nail, and more commonly the flesh around it, may become infected. This condition is called paronychia or "ringaround." The fold around the nail is red, swollen and painful; in severe cases it may be possible to squeeze out pus. The infection may result from impetigo

(to be discussed later), but more commonly it develops from injury to the tissue from too vigorous use of the orange stick, from biting and picking at the nails and particularly from "working" at hangnails.

Variations in the Pigment of the Skin.

The pigment in the deeper layers of the epithelium forms a screen against the penetration of light. A black surface absorbs more heat than does a white one. A white man can withstand heat as well as a Negro, but he has less protection against light. Some light rays are harmless; but the chemically active, actinic, or ultra-violet rays, in high concentration, kill tissues. The germicidal action of sunlight is due to the actinic rays. They are beneficial to health, particularly in the growing child, but in excessive amounts they are harmful to the skin. The skin pigment varies in response to the intensity of the rays striking upon it and thus tends to some extent to regulate the amount of light which penetrates the skin.

Tan and freckles are not caused by heat. Men who work in bakeries, laundries, or other hot places may have white skins, whereas mountain climbers burn and freckle amid the snow and ice of high altitudes. When exposure to sunlight ceases, the tan gradually disappears. Freckles, especially in the aged, often remain and may even appear on parts of the body which are not exposed to sunlight. Since the skin pigments are in the deeper layers of the epithelium, they can be removed only by stripping off the skin. Corrosive chemicals are sometimes sold as cosmetics for this purpose; their use is dangerous.

Pigmentation of the skin may occur from causes other than exposure to light. Thus repeated slight burns result in discoloration. Constant scratching of the chest and shoulders infected with body lice may lead to the stripes of pigmentation which are the characteristic sign of "vagabond's disease." A general pigmentation of the skin results from the prolonged use of arsenic. When silver nitrate is taken internally the salts of this metal may be deposited in the skin where they are reduced by exposure to light and color the skin a dusky blue, a condition called argyrea. Areas of pigmentation sometimes called "liver spots" may occur, especially on the faces of elderly persons, as a consequence of disease of the abdominal organs, the kidneys, liver, ovaries, or even the appendix. Similar discolorations of the skin may appear during pregnancy; in this condition the nipples of the breast normally become more deeply pigmented.

Moles are usually pigmented; but moles are more than simply pig-

mented areas of the skin. They are growths made up of a collection of epithelial cells which are beneath the surface epithelium. It is this deep growth which distinguishes them fundamentally from the cauliflower-like growth of warts, which rise from but do not extend into the corium. Moles, particularly those which are deeply pigmented, are to be treated with caution. They are occasionally the starting points of cancers, the so-called melanotic, or pigmented, and very malignant cancers. The vast majority of moles remain simply as cosmetic blemishes, but the liability to cancerous change is greatly increased by any irritation. It is therefore advisable to have moles removed whenever they are in localities where they become frequently irritated, as on the side of the nose of those who wear eyeglasses. Their removal should be done by a competent surgeon, and not with the types of treatment often applied to warts. A mole which shows a tendency to grow, or which presents a broken surface, should receive medical attention.

The pigmentation of the skin may be diminished as well as increased. Removal from sunlight leads to a bleaching of the skin—the "prison pallor"—through a process the reverse of the formation of tan. In the condition known as vitiligo, or leukoderma, areas of the skin and their hair become whitened. Small, round, white spots appear in the skin, and these spots increase in size until large areas of the surface are entirely devoid of pigment. The disease has no other features or effects than the decrease in pigmentation.

Influence of Bodily Condition upon the Skin.

As the skin is an organ of the body, just as is the liver or heart, it responds to those factors of health and disease which influence other organs. The rashes and eruptions which accompany such infectious diseases as scarlet fever, smallpox, chicken pox, typhoid fever and syphilis are simply the involvement of the skin by the disease. They are evident because the skin is exposed to the eye. Other organs of the body are also involved, and even more seriously than the skin, but the injury is not visible.

The hardening of the connective tissue throughout the body, usually as a result of age, has been mentioned above as the cause for the loss of youthful appearance in the skin. In severe varicose veins the circulation in the skin is diminished over the affected area. The skin hardens and becomes scaly, and ulcers form from slight wounds. Similarly, when the flow of lymph is impeded, the skin develops into a warty hide. The disease elephantiasis derives its name from the skin

change of this character. The disease is due to the plugging of the lymphatics of the legs by an animal parasite. A like condition of the legs, although much milder, sometimes results from wearing tight and narrow garters.

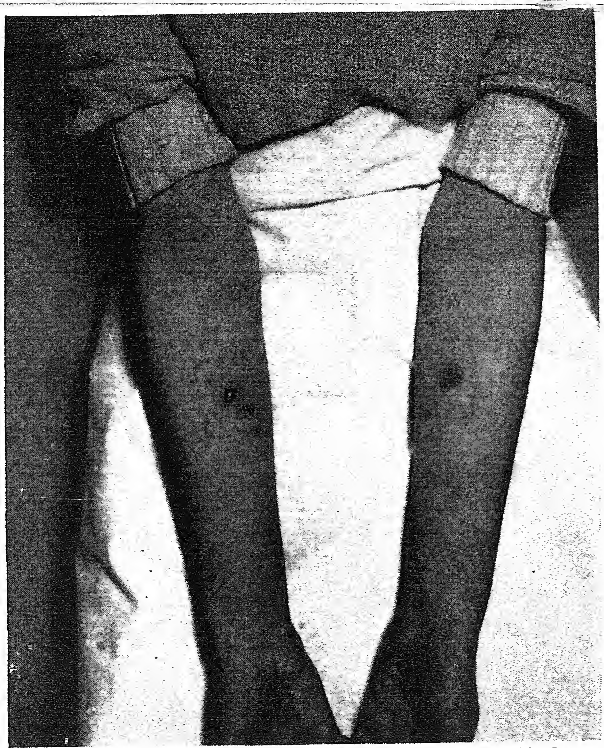
Inflammation of the Superficial Layers of the Skin, or Dermatitis.

Inflammation of the superficial layers of the skin occurs when the forces or agents acting upon it overcome the resistance which it offers and kill some of the tissue. Although inflammation is initiated by this destruction of tissue, the inflammation is a process distinct from the actual destruction and may appear some time after the tissues are killed. Thus when the skin is lightly burned the destruction of the tissue is not apparent, but inflammation develops later through the stages of reddening, swelling and blistering. Inflammation is a reaction characteristic only of living tissue. When the skin of a dead body is burned these inflammatory changes do not occur.

A substance or force which causes inflammation is known as an irritant. Irritation in this sense signifies merely that the agent injures in some manner or kills a part of the tissues with which it comes in contact. Inflammation is identical, regardless of the agent which inflicts the injury, but the degree of the reaction depends upon the extent of the tissues injured. Therefore the appearance of inflamed areas may differ widely according to the degree to which the inflammatory process progresses. Thus a scaly inflammation, following the use of laundry soap, arises through the same process as do the redness and blisters after a burn. The distinction depends only upon the differing intensity of the action of the two agents.

When an irritant is applied to the skin the first visible reaction is redness. This redness is due to the dilation of the small blood vessels in the skin. Fluid exudes from the vessels and passes into the loose tissues of the corium and between the epithelial cells. It is this exudation of fluid which causes the subsequent changes shown by the inflammation.

If the irritation is slight, only a small amount of fluid seeps between the epithelial cells. If this fluid continues to accumulate because of continuation of the irritation, the normal growth of the epithelial cells is altered. They form into coherent masses which are cast off as scales instead of singly and insensibly, as they are from the normal skin.



Courtesy Dr. M. Strauss

PLATE VI. Tests made to determine the cause of a dermatitis. See page 300. An eyelash dye and a skin lotion were under suspicion; a drop of each was placed on the skin of the forearms and covered with a square of adhesive tape. The photograph shows the conditions which developed a day later; both cosmetics caused skin irritation in this girl.

Courtesy Dr. M. Strauss

PLATE VII. Dermatitis of the feet caused by the dye from socks. See page 302.

Inflammation from the milder forms of irritation is thus of a scaly type, as in roughened or chapped hands.

If the amount of exudation is greater it seeps between the altered cells and makes its way to the surface. There the fluid coagulates and forms crust-like scabs over the scaly area. Under the action of more intense irritation the fluid exudes with such rapidity that the cells in the epidermis are pushed aside and little pools of fluid are formed among them. These collections of fluid are called vesicles and appear like minute blisters, although their mode of formation is somewhat different from that of a blister. White blood corpuscles often collect in the vesicles and the otherwise clear fluid then becomes white and turbid. The name pustule is then applied instead of vesicle. The amount of fluid exuded in the tissues may be so great that the altered cells in the outer layers of the skin are washed away. There is left then a raw surface from which drops of fluid exude.

If the irritation is intense the reaction is so acute that large amounts of fluid are thrown out into the tissues before the growth of the cells has been altered. The skin then separates in a layer from the underlying tissues with the formation of a blister or bleb.

Dermatitis often shows concurrently several phases of the phenomena here described. Thus scales and vesicles or even raw spots may appear together in the same inflamed area.

Dermatitis caused by an irritation may be complicated and aggravated by infection. Moreover, the infection does not at once disappear when the original cause of the dermatitis is detected and eliminated. A group of closely related bacteria, which from their shape and type of growth are known as staphylococci, are always found on the skin. Even the most thorough washing cannot entirely rid the surface of them. Normally these bacteria are harmless. The exudation from an inflamed surface furnishes a medium in which they can multiply rapidly. As a result of this luxuriant growth, the virulence of the bacteria is increased so that they cease to be harmless.

The skin of different individuals and the skin on different parts of the body may show wide differences in susceptibility to irritants. Children are usually more sensitive than adults. Some individuals, however, are abnormally susceptible to irritation from substances which are harmless to most individuals. They show what is essentially an allergic reaction. Thus toilet preparations intended to beautify the skin may cause marked irritation in susceptible individuals. Certain dyes in the clothes, the juices of common and non-poisonous plants,

and even the ink from the illustrated papers may irritate their skin. Numerous cases of intense dermatitis resulting in blindness have occurred in susceptible individuals from a dye, paraphenylendiamine, used to darken hair.

Sensitivity may develop quite rapidly and for reasons unknown, so that severe dermatitis occasionally results from contact with substances which were previously handled with impunity. It is often difficult to discover the offending substance; usually to do so it is necessary to put on separate small areas of the skin, as patch tests, minute amounts of every conceivable substance with which the individual comes in contact. Redness in the test area indicates an irritating substance.

Plant Dermatitis.

Poison ivy, poison oak, poison sumac, and the primrose are the most common causes of plant dermatitis. There are, however, more than a hundred other plants which from prolonged contact or in susceptible individuals may produce dermatitis. There is great individual difference in susceptibility to plant dermatitis, especially poison ivy.

In most of the plants which cause dermatitis the irritating agent is an oil or resin. It may reach the skin by direct contact or through an intermediary agent which has touched the plant—clothing, cordwood, croquet and tennis balls, shoes, garden implements and dogs. It may also be carried in the smoke from the burning plants.

For a short time after the irritant reaches the skin it may be possible (this is a debated question) to remove it by washing the area of contact with soap and water, alcohol or gasoline. Injection of the toxin from ivy leaves has been used to increase resistance to poison ivy dermatitis. This and the older methods of chewing the ivy leaves or drinking a watery solution of the irritant, should be undertaken only under the advice and supervision of a physician.

After exposure to poison ivy the dermatitis develops within twenty-four to forty-eight hours. Before the appearance of the inflammation the oil or resin on the skin may be spread by the hands to many parts of the body. The dermatitis runs a course of one to several weeks, depending upon the severity of the inflammation. In spite of many remedies advocated, there is no cure for the condition although considerable relief can be obtained from mild and soothing applications. Strong antiseptics, such as iodine or other irritating substances, should not be used in treatment.

Occupational Dermatitis.

Every occupation brings the worker in contact with irritants of the skin as both physical and chemical agents. Although the causes of dermatitis are thus almost universal, dermatitis develops only when an irritant is encountered in such strength or with such persistence that it overcomes the resistance of the skin. Thus almost everyone is exposed to sunlight and, for the most part, without injurious effects. Nevertheless, exposure to intense sunlight produces sunburn, which is a typical acute dermatitis. Similarly, many persons use soap and water upon their skin without untoward effects, but for the washwoman and scrubwoman these substances may excite dermatitis.

The commonest occupational irritant is soap and water. Red and roughened hands from dishwashing and laundry work are the mildest form of chronic dermatitis. The stronger cleaning materials used by scrubwomen and washwomen are proportionally more irritating. The dermatitis is often of sufficient severity to deserve the distinctive name of "washwoman's dermatitis." A similar condition occurs in the hands of barbers, washers of automobiles and, in fact, among the workers in any occupation involving the frequent use of soap and water.

The salts of certain metals, either in solution or as dust, produce severe inflammation of the skin. Chromic acid and the salts of chromium are particularly irritating, as are also the salts of mercury and arsenic. Lime dust is a common cause of dermatitis. Portland cement has a similar action, although to a less degree. Both of these substances will produce ulcers if applied in sufficient strength. The septum of the nose is particularly vulnerable to irritating dust and may even be perforated by the ulcers which form.

It is a difficult problem to protect the hands against the action of irritating solutions if the exposure is of daily occurrence. Theoretically rubber gloves offer complete protection, but in practice their use has many objections. Waterproof materials next to the skin induce heavy sweating, especially when working with hot liquids. The sweat softens and removes the horny layer, and thus renders the skin tender, thin, and more vulnerable to the action of chemicals.

Occupational dermatitis often presents a difficult problem in industry. Dermatitis may be limited to a few workmen and may occur from seemingly unlikely substances.

Physical Agents.

Constant pressure against the skin causes it to become thin, while intermittent pressure or friction stimulates the skin to increased growth, providing the pressure is not sufficient to cause ulceration. Calluses result from intermittent pressure upon the skin. A man in starting work with a pick and shovel develops a characteristic series of changes in the skin of his hands. After a few hours of work the skin becomes thin and sore, and looks red and glazed; sometimes it blisters. In the course of a day or two the outer layers peel off. The skin which is then formed is thicker than formerly. Sensibility is diminished in these calloused areas and pressure is no longer felt. The nature of the man's occupation can often be told by the position of the calluses.

A corn originates in the same manner as a callus, but usually only on the feet. The chief cause is badly fitting shoes. A corn is distinguished from a callus by the presence of a central ingrowth of the horny layer of the skin. This ingrowth is in the shape of a cone pointing downward. Its growth compresses the underlying layers of the skin which become thinner, and a cup-shaped cavity is left when the corn is removed. Pain is caused by the pressure of the central ingrowth against the sensitive layers of the skin. A corn occurring between the toes absorbs sweat and appears white and sodden.

Sunburn.

Sunburn, snowburn, and waterburn are different names applied to the same condition—dermatitis caused by the irritation from ultra-violet light. Not only the sun's rays but also the emanations from the electric arc, the electric and acetylene welding flames, and from the mercury quartz lamps contain ultra-violet light.

In high altitudes the sun's rays are rich in ultra-violet light; by reflection from the snow the burn may appear most markedly on the chin and undersurface of the nose. Near water the sun's rays passing through the cooled air lose much of the red heat waves, and the individual exposed, not feeling the discomfort of the heat, is not warned of the danger from the short, painless actinic rays until the skin is severely injured.

There is great individual difference in susceptibility to ultra-violet light. Blonds are more susceptible than brunettes; brown and black-skinned people, like the Arabs and Negroes, do not sunburn. A greasy skin offers more protection than a dry skin, and greasy substances, especially those which fluoresce in ultra-violet light, when applied to

the skin, protect it from sunburn. Certain colors, through their property of absorbing ultra-violet light, likewise give protection. Thus a thin veil of red or yellow fabric may prevent sunburn.

Occasional individuals show toward sunlight an almost allergic reaction, burning after slight exposure; they have what is known as sun poisoning. This condition is intensified by lack of vitamin B. A number of drugs taken internally or applied to the skin increase the sensitivity to ultra-violet light.

The severity of sunburn varies from a mild redness of the skin to swelling with blisters. In some cases there may be illness and fever. From prolonged exposure to ultra-violet light among susceptible individuals, particularly after middle age, the skin degenerates. It becomes dry, thin, and inelastic, a condition known variously as sailor's skin, farmer's skin and tropical skin.

Effect of Freezing on the Skin.

Chilling of the skin causes the blood vessels to contract, thus lessening the flow of blood to the area. Severe chilling may close the vessels completely, thus shutting off the circulation. The area thus deprived of its circulation is easily frozen. There is no pain during the freezing, and onlookers are more likely to recognize the condition than the individual affected. The frozen part appears shrunken, dull and waxy. Freezing occurs most often in the extremities and in exposed parts such as the nose and ears. Children and old people are more susceptible than vigorous adults.

Some days after the freezing the part gradually shrivels, turns black, and is either absorbed or sloughed off. Even when the tissues are not killed, inflammation may result from the stoppage of the circulation. The effect is not felt until the circulation is restored by warmth. Fluid from the returning blood exudes from the vessels, which are now relaxed. Inflammation develops, with the same sequence of events as in any other dermatitis. The circulation should be restored slowly to the chilled part in order to avoid the inflammation which follows sudden reestablishment. The part should be immersed in cold water and rubbed gently; if actually frozen it may be rubbed with snow. As the circulation is restored the temperature of the bath is gradually elevated. A chilled or frozen part should never be exposed at once to heat.

The constriction of the blood vessels caused by cold is often exacerbated in the feet by the shrinking of the wet leather of the shoes.

The suppression of the circulation by this combination of conditions may lead to gangrene, that is, death, in the toes or even in the entire foot. In such cases amputation is necessary. "Trench feet," as this condition was named during the European War, is not limited to soldiers in trench warfare, but may occur in anyone who is inactive while exposed to wet and cold, and wearing shoes which are not waterproof. The tramp sleeping on the park bench in the early spring or late fall sometimes develops trench feet. Preventive measures consist in wearing loose, waterproof covering for the legs and feet and maintaining as much movement as possible.

Effect of Heat on the Skin.

Burns are caused by dry heat from the contact or proximity of a flame or heated solid body. Scalds are caused by moist heat from the action of heated fluids, steam, or other hot vapors. The difference in effect is comparable to the distinction between roasting and boiling. The skin, and even the underlying tissues, may be destroyed by the heat and the inflammation which results.

Burns are usually classified in three different degrees which express the extent to which the flesh is destroyed. (The surgical classification includes six degrees, the third degree of the simple classification given here having four subdivisions.) In burns of the first degree the destruction of the tissues extends to only a slight depth. There is pain and reddening of the skin and subsequent loss of the superficial layers. In burns of the second degree there is, in addition to the reddening seen in first-degree burns, a formation of blisters either immediately or within a few hours. When the blister bursts and the cuticle is removed the corium is left exposed and is red and painful. In burns of the third degree the skin is destroyed and charred to its full depth, and even deeper structures, such as fat, bone and muscle, may be burned.

In burns of the first and second degree the full depth of the skin is not destroyed. During healing, therefore, the skin is readily replaced from the undamaged layer and no scar develops. Burns of the third degree, however, result in scars. The extent and nature of the scar formation depend upon the depth to which the tissues are destroyed. In severe burns of the third degree it may be necessary to graft skin to complete the healing. The scars which form in these severe burns contract and pull in the sides of the wound. If the area is large, unsightly puckered scars are thus produced, and if the burn is between movable parts deformity may result. Thus if the palm is involved,

the hand may be pulled into a claw, or if the burn is at the elbow, the forearm may be pulled up and held against the upper arm. Such deformities from contraction of the scar can often be prevented by holding the structures extended by means of splints during healing.

Aside from the local wound, burns and scalds have a general effect upon the body in proportion to the area of the surface affected. A burn or scald of the second or third degree covering one-third or more of the surface of the body is frequently fatal. In burns over smaller areas there may be illness and fever. These general effects are presumably due to the absorption into the blood of products from the burnt tissue.

In burns of the first degree (and also sunburn) application of a compress kept wet with a saturated solution of boric acid or a dilute solution of sodium bicarbonate helps to relieve the discomfort. A day or two later cold cream may be used advantageously. A useful application for slight burns is the so-called carron oil, composed of equal parts of lime water and linseed or olive oil. The most satisfactory treatment of all second- and third-degree burns is the application of tannic acid solution in a strength of 2.5 to 5.0 per cent. The tannic acid coagulates the protein in the raw surface; it relieves pain and assists in preventing the absorption of products from the burnt tissue.

Herpes.

The common fever blister or cold sore is known as herpes simplex. Herpes appear most commonly on or near the lips, either outside or inside; they may also occur on the cheek, ear or genital organs. The condition develops suddenly with the appearance of a group of vesicles which tingle or burn; a crust forms over the mass. Usually the herpes dry up within a week or two, leaving no scar. Application of spirits of camphor or alum may hasten healing.

Herpes simplex may apparently develop from several causes. In some cases the disease is produced by a filterable virus and is then communicable; in others it appears to result from nervous strain, indigestion, sunburn, and as a complication of many infections such as malaria, pneumonia, influenza and even head colds.

In contrast to herpes simplex the condition called herpes zoster, or shingles, appears to be a definite infectious disease. The cause is probably a filterable virus which is presumed to act on the spinal cord. The sores, which resemble those of herpes simplex, appear on the skin over the tips of the nerves. The spreading, often fan-shaped

distribution of the herpes may cover a considerable area of skin. In the young the condition is nearly painless; in the middle-aged and particularly the aged, it may be highly painful. Sometimes the pain persists long after the herpes have disappeared from the skin.

The disease is self-limited, lasting from two to three weeks; treatment does not appear to shorten the attack but may give relief from the pain. The greatest danger of herpes zoster is that the eyes may lie in the course of the extension; herpes appearing on the cornea may lead to scarring, with possible danger to sight.

Impetigo Contagiosa.

Physical and chemical agents are not the only causes of inflammation of the skin; bacteria and fungi which attack the surface layers of the skin likewise produce inflammation. The diseases thus caused are communicable.

Impetigo contagiosa is a common infectious dermatitis. It is caused by the streptococcus or the staphylococcus (see page 545). Impetigo commonly appears on the face and commences as a red spot which rapidly becomes a vesicle, or even a blister, and then a pustule. The pustule dries into a yellowish crust, which appears loosely attached to the skin.

Impetigo spreads rapidly from person to person by contact. The disease is common in schools, where it may assume epidemic proportions, especially among those engaged in athletics necessitating close contact, such as wrestling and football. The disease sometimes goes by the name of football itch. It is not to be confused with ringworm, which is a fungus growth on the skin also common among those engaged in athletics, and which generally occurs on the groin, feet or hands.

If left to itself, impetigo will go on indefinitely, reinoculating itself on different parts of the body. Mild cases, and those detected early, usually respond quickly to medical treatment. The disease has for adults no complications of serious nature; it causes no general illness. It may, however, be a serious disease for infants.

Erysipelas.

Erysipelas, like impetigo, is caused by the streptococcus but of a far more virulent strain. It is the so-called hemolytic streptococcus, closely related to the variety which causes scarlet fever. In contrast to impetigo, the infection goes deeply into the skin, is spread through the lymph

channels and is a serious disease with profound systemic effects and sometimes fatal consequences. The disease starts most often on the face, usually near the nose. There is first fever and a feeling of illness and discomfort. There then develops an elevated pink or reddish area which gives a burning sensation. The inflammation spreads symmetrically from the original center, maintaining a sharply defined and elevated margin. The entire face becomes swollen; the inflammation generally spreads in the course of a week to the ears, upward into the scalp, and downward as far as the neck. At these limits it usually stops. The temperature, which has ranged between 102° and 105°, then subsides. The illness disappears and the skin gradually returns to normal.

Erysipelas is not limited to the face but may occur on any part of the body from the infection of a wound.

Anthrax.

Anthrax is primarily a disease of herbivorous animals, particularly sheep, goats and cattle. The infective agent is the anthrax bacillus. This organism has the property of forming spores. The anthrax bacillus itself is readily killed, but the spores are highly resistant and may remain for many months clinging to hides, wool or hair, by which they are transmitted to man. When brought into a suitable environment these spores develop into anthrax bacilli.

Man may be infected with anthrax in the intestines, lungs or skin. The intestinal form results from eating the meat or drinking the milk of infected animals, and occasionally from bacteria carried to the mouth from an infected area on the man's skin. The symptoms of intestinal anthrax are those of cholera; the mortality is high. Anthrax of the lungs is called "wool-sorters' disease" or "rag-pickers' disease" from the prevalence of the infection among men engaged in these occupations. The bacteria are carried into the respiratory passages in the dust from infected materials. Like the intestinal form, the disease is acute and generally fatal.

Anthrax of the skin occurs chiefly among those engaged in handling hides, wool or hair. It has been known, however, to follow the wearing of a coat lined with sheepskin. A recent epidemic was traced to the hair in shaving brushes. Infection of the skin starts as an itching red spot resembling the bite of an insect. The inflammation spreads rapidly and within a few hours a reddish-black area appears; the skin

about it is swollen and inflamed. In severe cases the bacteria are disseminated throughout the body.

An anti-anthrax serum is now available for treating the disease. Prevention of the disease consists in disinfecting the hides, hair and wool, particularly those imported from Mongolia, Persia, Russia and India. There is very little anthrax among the animals of the United States; it is extremely important to prevent its occurrence.

Acne.

Acne is a disease that affects in some degree nearly everyone; it occurs mainly between the ages of twelve and twenty-five. It is a more or less chronic infection of the sebaceous glands, especially those of the face, chest, back, and genitals. Acne results in blackheads, or comedones, and pimples; in severe and prolonged cases the face may be scarred and deformed.

Acne is usually associated with an oversecretion of grease from the sebaceous glands. The mouths of the grease glands become blocked with small oval bodies, comedones, composed of epithelial cells and dried grease. The long coil of yellowish material which can be expressed from the gland when the blackhead is removed is sebaceous secretion which has accumulated in the gland. The distended sebaceous glands often become infected with the bacteria normally found in the skin. Pus develops in the glands forming pimples.

Acne is not an infectious disease in the sense that it is transmitted by contact. The disturbance in the secretion of grease with which it is usually connected appears to be associated with the changing activity of the glands of internal secretion occurring at puberty and during adolescence. In some individuals the disease is made worse by eating excessive amounts of carbohydrates; alcohol may also exert this action. In all cases iodides and bromides (the latter are often taken as sedatives and headache remedies) make acne worse; these chemicals in excessive amounts will of themselves produce a skin eruption.

Acne is often difficult to eradicate, but much improvement can be effected by proper treatment. The comedones should be removed gently to avoid bruising the skin; pimples should be touched with a drop of antiseptic, opened only with a sterilized needle, and squeezed gently to prevent forcing the pus deeper into the skin. The affected area should be washed frequently with soap and hot water. All greasy applications are to be avoided. The skin of people over thirty may sometimes be benefited by greasing, but not that of young people unless it is chapped.

Facial massages are to be avoided. The general health should be cared for by proper food, fresh air, exercise and sufficient sleep. Sunlight often exerts a beneficial effect on acne, the condition clearing up in the summertime and recurring in the winter. In cases that threaten to be severe, a dermatologist may render valuable service with treatments that can be given only under medical supervision. The proprietary ointments and salves sold for the treatment of acne may do more harm than good, although they all effect a "cure" if used until the age when the disease naturally disappears.

Oil Acne.

Infections of the skin, and particularly acne, often follow repeated wetting of the skin with oil. There are two ways in which these infections are produced. One is the inoculation of scratches with pus-forming bacteria. Oil which is used repeatedly as a lubricant in cutting in machine shops becomes highly contaminated with bacteria. Scratches are often caused by tiny particles of metal. Such particles are carried in the oil and lodge between the fingers, or are caught in rags and waste and cut the hands as they are wiped. This type of infection is readily overcome by filtering the oil each time it is pumped through the machine and by sterilizing it daily with heat. The addition of disinfectants to accomplish the sterilization is not satisfactory, for the disinfectants themselves are irritants and may cause dermatitis.

A second type of disturbance from oil centers in the grease glands and usually appears as acne or boils. The acne is produced primarily by the stimulating action of the oil upon the growth of the epithelial cells; typical comedones and acne pustules appear. The boils result from the infection of the hair follicles and grease glands with bacteria carried in the oil. Certain oils, particularly those from coal tar, have the property of stimulating the skin to excessive growth; they may also cause warts and in some instances even cancer.

Boils and Carbuncles.

A boil or furuncle is an infection usually about a hair follicle and extending deeper into the skin than a pimple. The inflammation causes swelling and pain; pus is formed and surrounds a mass of dead tissue, a core, in the center of the boil. Boils tend to occur whenever there is friction of clothing against the skin as on the back of the neck and the buttocks. Clean underclothing and shirts—and for athletes, clean trunks, suits and mats—are primary steps toward preventing boils. But

even the greatest cleanliness does not always ward them off. Moreover, they tend often to appear in crops, one following another in rapid succession, a condition called furunculosis.

When first appearing, a boil may sometimes be checked by painting the inflamed skin with tincture of iodine and then chilling it with cold applications. Preventive treatment failing, the course of the boil can be hastened and the boil "brought to a head" with hot applications. Poultices are often used for this purpose, but unless they are made of material that can be rendered antiseptic they are best avoided.

A carbuncle is essentially a number of boils occurring together. It is a far more serious condition than a boil and is often accompanied by fever and illness. It can be treated safely only by a physician.

Ringworm.

There are many diseases occurring both in man and in brute animals caused by the growth of fungi on the skin. These fungi do not spread into the body to cause general infection as do bacteria. The disturbances they cause on the surface are, except for acne, the most common skin diseases. There are twenty or more varieties of fungi known to infect the skin, causing the various disturbances loosely grouped here as ringworm. The infection may occur on the scalp, particularly of children; it may also occur on the face where it takes two common forms: the typical ringworm, spreading out as a red ring and healing in the center as it widens; and a much deeper and more severe sort known as barber's itch which affects the beard region in men. The latter variety may be acquired from domestic animals and is most common among farmers and horsemen.

Ringworm may occur on the eyelids and about the opening of the ear where it is often mistaken for eczema. Among men, particularly those engaged in athletics, ringworm infection may develop in the groin as "jock strap" or dobie itch. It may occur here secondarily to an infection on the feet, or develop independently. The infection in the groin is not to be mistaken for chafing which frequently occurs in this region. The ringworm infection has sharp margins, and the crusted sores are raised above the general level of the skin. Under prompt treatment this form of ringworm usually clears up quickly; if neglected it may spread widely over the abdomen.

No part of the skin is exempt from fungous infection, but by far the commonest location is the feet. It occurs particularly in young adults, and especially those who perspire freely. The disease is chronic, the

symptoms tending to go away under treatment and to recur when the treatment is stopped. Ringworm of the feet varies greatly in severity; mild cases show only a mass of soft sodden whitish skin between the toes, often with cracks; in severe cases there are vesicles and blisters followed by raw areas and scales. The disease may be limited to a small area or may extend over the entire foot. It may also be carried from there to other parts of the body. The wearing of black socks and black shoes often aggravates the condition.

The treatment of ringworm in any of its forms should be carried out by a dermatologist. Home treatment is usually far from satisfactory; the disease may get out of control and spread widely. The infected individual should devote his own efforts to preventing the spread of the disease to his family and associates.

The fungi from the feet are deposited everywhere the bare feet are placed. The organisms on rugs, in cracks in floors, shoes, clothing, may remain alive for as long as a year. Most of the fungi are killed by hot water, so that scalding the bath tub and laundering towels and clothing usually frees them from the fungi. After bathing it is a poor practice to dry the feet first and then the groin.

Leprosy.

Leprosy is caused by a bacillus which closely resembles that of tuberculosis. The bacillus of leprosy produces lumps or tubercles similar to the nodules in tuberculosis. The lesion of leprosy, however, is limited to the skin, the mucous membrane of the nose and mouth, and the nerves. The first symptoms usually appear as changes in the skin. Sharply defined areas become reddened and finally pigmented. Occasionally the pigmentation disappears and a white area is left. This blanching is rare in leprosy, but probably from Biblical description is associated in the popular mind as a regular and characteristic sign of the disease. Consequently, the comparatively common disease leucoderma often gives rise to the suspicion of leprosy.

Leprosy is a very ancient disease, but under the Hebrew term used in the Bible and translated as leprosy there are embraced apparently many skin diseases other than leprosy. The disease was prevalent throughout Europe during the fourteenth and fifteenth centuries. During the sixteenth century a marked decline occurred as a result of segregation and general improvement in living conditions. Today the disease is widely prevalent in only a few areas, mainly in the East. Leprosy was introduced into the Hawaiian Islands about 1859. The

conditions there were favorable for propagation of the disease; it spread rapidly among the natives and nearly 3 per cent became leprous. Strenuous efforts have been made to stamp it out by segregating the lepers on the Island of Molokai.

Few diseases inspire such fear of infection in the minds of most people as does leprosy; but in reality it is difficult to transmit the disease. The bacilli are present in the open sores, and in the sputum and nasal secretions when the mucous membrane of the nose and throat is involved. The disease is unquestionably communicated directly from the sick to the well, but except in rare cases prolonged and intimate contact seems necessary for the transmission. Leprosy does not spread among those who are clean. Very few nurses and doctors in attendance at leper colonies have contracted the disease. Crowding and the conditions of poverty promote its spread. As soon as a country becomes economically able to adopt the tidiness of modern civilized life, leprosy dies out. The children of lepers are not born with the disease.

Leprosy has a remarkably long period of incubation, often a matter of years. There is no certain curative treatment for the disease, but good hygienic care as in the treatment of tuberculosis seems to be beneficial. Often improvement is obtained by the use of medicaments made from the oil expressed from a nut native to southern Asia. It is known as chaulmoogra oil and has been used in the oriental countries for centuries in the treatment of leprosy.

CHAPTER XIII

PARASITES AND THE DISEASES THEY CARRY

A VARIETY OF INSECTS PREY UPON MAN AS THEIR SOURCE OF FOOD. THESE parasites attack the skin and their bite produces irritation and inflammation. The itching induces scratching, which carries into the wound any infectious material on the skin adjacent to the bite or upon the fingers. These local effects are, however, less important than the infectious diseases which may be transmitted by the parasites. Insects form an essential step in the transfer of the germs of such diseases as malaria, yellow fever, bubonic plague, and the African sleeping sickness.

Lice.

Pediculi, or lice, are flat, elongated, wingless insects with stout legs ending in sharp claws. In front is a short beak or proboscis through which extends a slender stylet used to puncture the skin. In feeding, blood is sucked through the proboscis. Three species of the louse prey upon man: Pediculus capitis, the head louse, Pediculus corporis, the body louse, and Pediculus pubis, the crab louse. Some individuals are highly susceptible to infestation by lice, particularly body and head lice; others are singularly unsusceptible. It is unusual for children to harbor body lice, though they readily become infested with head lice.

Head Lice.

The head louse centers its activities on the scalp, more particularly the rear portion. The eggs are firmly cemented to the hairs and can readily be seen as white specks known as nits. The bite of the head louse gives rise to crusted sores. In severe cases the hair becomes tangled in these scabs and matted together, forming a firm crust, or "plica polonica," so named because of its relatively frequent occurrence among the Jews of Poland. The lymph glands at the back of the neck swell from the drainage of the infected areas. Head lice are commonest among people of unclean habits, but children of the better classes may become infected from playmates or nurses.

Bathing the scalp with kerosene oil, either full strength or mixed with

an equal quantity of olive oil, kills the parasites. This procedure should not be carried out in a room where there is an open fire or an electric heater. After a few hours the scalp should be shampooed. The nits are loosened by rinsing the hair in diluted vinegar and may be removed with a fine comb.

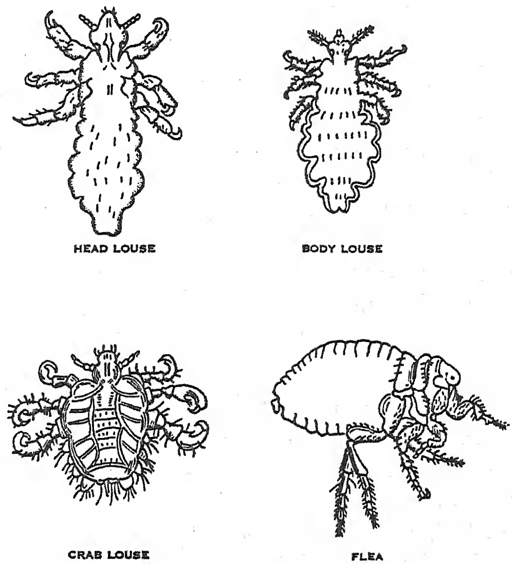


Figure 46. COMMON PARASITES OF THE SKIN.

Body Lice.

The Pediculus corporis, or body louse (the cootie of the late war), lives in the clothing, particularly the seams, and goes to the body only for food. The bite causes minute hemorrhagic spots which itch intensely. The bodies of those infested show linear abrasions on the skin about the neck, back and abdomen, made by scratching. In chronic cases these scratch marks become permanently pigmented and characterize the condition known as vagabond's disease. The prevention of body lice is almost entirely a matter of personal cleanliness. Anyone may become infected with lice by contact in crowds or trains, or indirectly through beds in hotels and sleeping cars. No one should be blamed for having lice, but only for keeping them. The lice on the clothing are killed by laundering and dry cleaning; they can be removed from the body by a hot bath.

Crab Lice.

The crab louse attacks the region covered by the pubic hair; in persistent infestation the parasite may migrate to the hair of the chest and armpits and also the eyebrows. The louse is acquired by contact or indirectly from unsanitary water closets and privies. Itching is the most marked symptom of infestation. The louse usually attaches itself to the base of the hair and is often mistaken for dirt particles; the brownish granules of excrement from the parasites may be seen entangled in the hair. Shaving the hair from the affected region is the most satisfactory form of treatment. The mercurial ointment, blue ointment, often used in home treatment, is best avoided except under the supervision of a physician. Continued application may lead to severe dermatitis.

Typhus Fever.

The body louse is the main transmitting agent for the germ of typhus fever. There is evidence that occasionally the head louse, the bedbug and the rat flea may also spread the disease. Although there is a confusing similarity in names, typhus fever and typhoid fever are entirely different diseases. Typhus is caused by an extremely minute organism, smaller than ordinary bacteria, belonging to the class known as Rickettsia. Typhus prevails in epidemic form only in overcrowded and filthy surroundings and is therefore sometimes called jail fever, camp fever or ship fever. The crowding and other unhygienic conditions in lands devastated by war allow the disease to spread among the soldiers, prisoners and refugees, as in Serbia in 1915. In such epidemics the mortality is high, ranging between 20 and 70 per cent.

The disease occurs in a much milder form endemically in parts of Mexico; it is known there as tabardillo. A still milder form, often called Brill's disease, occasionally appears along the Atlantic seaboard. The mortality is only about 2 per cent. Typhus is sudden in its onset; there is fever and prostration which in severe cases is extreme. On about the fourth day a skin eruption appears. In favorable cases the fever drops by the end of two weeks.

Bedbugs.

The common bedbug does not live in as close association with the body as does the louse. Nevertheless, this insect has become a thoroughly domesticated animal in all parts of the world. The bedbug hides in the crevices of wooden bedsteads and in cracks in the floor and

walls. It is nocturnal in its habits. It punctures the skin and feeds upon blood, but may live for long periods without feeding.

The occasional presence of bedbugs in a house is not necessarily an indication of neglect, but, as in the case of lice, their retention is. The insect is usually introduced upon the clothing of visitors or servants, or in the baggage of travelers; it may come back in the clean clothes from the laundress. The bedbug is suspected of occasionally assisting in the transfer of communicable diseases, but is not an important factor.

The common red ant and the cockroach are natural enemies of the bedbug. In addition to the ordinary bedbug, cimex lectularius, there are numerous other species native to different regions; although some of them may occasionally prey upon man, most do not, but are parasites of bats and birds.

Fleas.

Fleas are wingless, blood-sucking parasites which can both crawl and leap. Their ability in this last respect has been greatly exaggerated in the popular mind. Fleas can jump to a height of three to five inches, but seldom over six, a point of considerable practical importance in preventing infection from the ground. Fleas cannot cling to the smooth surface of rubber boots; they cannot reach the top. There are many species of fleas; the more common are known by the names of the animals which they ordinarily infest—the dog flea, or Ctenocephalus canis; the cat flea, Ctenocephalus felis; the common rat flea, Ceratophyllus fasciatus; the squirrel flea, Ceratophyllus acutus; and the common flea, Pulex irritans. Although the fleas as a rule prefer certain hosts, they are not as particular in this regard as are many parasites. The species mentioned above will attack several hosts, including man. This democratic tendency on the part of fleas makes them particularly dangerous parasites, for they are the bearers to man of a disease of rodents, the bubonic fever, or plague.

Bubonic Plague.

Bubonic plague is primarily a disease of rats and secondarily of man. The flea affords the necessary transmitting agent both from rat to rat and from rat to man. Bubonic plague is the famous "Black Death" which swept through Europe in the fourteenth century, destroying a quarter or more of the population; severe epidemics continued there until late in the seventeenth century. The disease persists today in Asia

and India, where there have been more than ten million deaths from it in the last twenty years. Plague is occasionally found in the rats in Hawaii and the ground squirrels of California. The disease has never assumed serious epidemic form in the United States.

Plague is caused by the so-called pest bacillus and appears in two main forms: the common, or bubonic plague, and the less common pneumonic plague. In both types there is intense illness with high fever. In the bubonic form the lymph glands, usually in the groin, become swollen on the second or third day of the disease and fill with pus. Such swollen and suppurating glands are known as buboes, from which the disease derives its name. Hemorrhages may occur under the skin. When the plague ravaged Europe the dark areas from these hemorrhages were known as "plague spots" and gave the name "Black Death." Bubonic plague has a mortality of about 75 per cent; the pneumonic form of the disease, nearly 100 per cent.

Bubonic plague is not transmitted by contact but only through the intervention of the flea; pneumonic plague is spread directly from person to person. In the bubonic form the pest bacilli are centered mainly in the lymph glands, and although they are present in the blood they do not appear in the sputum or nasal secretion. In the pneumonic form of plague the disease is centered in the lungs; the bacilli are present in the secretions.

In non-fatal cases of plague the fever begins to diminish about the seventh day. One attack of the disease usually protects against a second. A fair degree of artificial immunity can be obtained for a few weeks, or months, by the use of anti-plague vaccines.

The prevention of bubonic plague demands either the eradication of fleas or the eradication of rats. The first is impossible; the second, except in limited areas, appears to be almost equally hopeless. The number of rats in cities and upon farms is tremendous; it is estimated that there are some twenty or thirty million rats on the Island of Manhattan alone. The damage to food by rats is enormous; it costs at least a dollar a year to support each rat. To this direct damage must be added the injury to buildings and their contents, for rats not only destroy materials to build nests and to make passageways, but gnaw indiscriminately to wear down their rapidly growing incisor teeth. Consequently rats will attack woodwork, lead water pipe, the lead coating of electric cables, and even plaster. These economic losses are secondary to the great menace of the plague. Because of the difficulty of eradicating rats, the quarantine efforts of the United States to pre-

vent the introduction of plague are largely confined to protecting the local rats from acquiring the disease through the immigration of rats with the plague. In ships coming from parts of the world where there is plague, rats on board are killed by fumigation. Sulphur dioxide and hydrocyanic acid gas are the main agents used for this purpose. These fumigants have the advantage of also killing the fleas with which the rats are infested.

Rats breed with such enormous rapidity that anything short of complete extermination is of only temporary effect. It has been shown that the number of rats is dependent upon their food supply. If their access to food is restricted, they eat each other and so limit their own numbers. The moral of this is evident. Ratproofing of places where food is stored is the one essential and effective measure.

Mosquitoes.

The mosquito is a blood-sucking parasite. It only infests man temporarily in order to feed. Unfortunately, it is not regarded with the odium attached to the louse, flea or bedbug. Nevertheless, of these four, the mosquito is the most deadly insect. It transmits malaria, yellow fever, and the less common tropical diseases, dengue and filariasis. The loss of life and the total of ill health and diminished vigor resulting from the first two of these diseases far exceed the ravages of the more spectacular typhus or plague for which the louse and flea are responsible.

Male mosquitoes are vegetarians, but to the females of most of the species blood is indispensable for the formation of eggs. All but the adult stage of the development of the mosquito are aquatic. The eggs are laid in water and hatch into larvae, or "wigglers." Although these larvae are aquatic they breathe air through a small tube which they project at intervals above the surface. After about a week the larvae pass into the pupa stage, from which the adult mosquito emerges a day or two later. The stagnant water of pools, ponds, ditches and marshes forms the natural breeding place of mosquitoes. Even small and temporary deposits of rain water left in hollows or footprints may serve. No body of water is too small for a mosquito hatchery and nursery. Mosquitoes will breed in the water held in cisterns, cesspools, barrels, fire buckets, sagging gutters of houses, broken bottles, tin cans, and hollows in trees.

Mosquitoes can be kept out of houses by screening, but a much more satisfactory method of control is the complete eradication of these

insects. Although mosquitoes may be carried to considerable distances by the wind, they do not fly more than half a mile from their breeding place. Thus the eradication of all breeding places within a comparatively small radius from a house or town rids it of all except the mosquitoes blown in by the wind. The most satisfactory method of destroying the natural breeding places is by drainage and filling. When such radical methods are not practicable the next resort is oiling. A film of

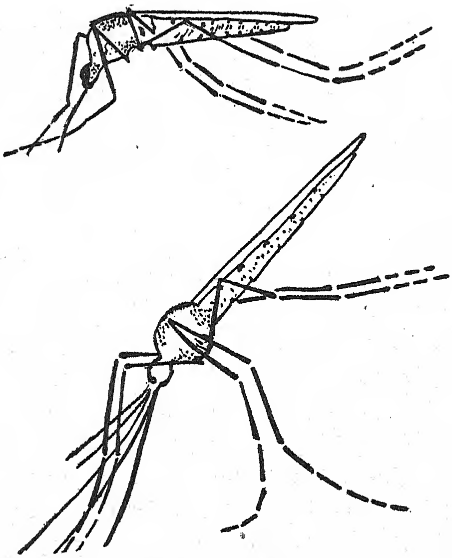


Figure 47. THE CULEX AND ANOPHELES MOSQUITOES IN THE POSITIONS FROM WHICH THEY DRAW BLOOD.

oil upon the water prevents the larvae from breathing and thus suffocates them. Sufficient oil is applied to cover the entire surface with a thin film. The oil must be renewed at frequent intervals. In addition to controlling the natural breeding places, all artificial deposits of water, such as cisterns, tin cans, and the like must be either screened or emptied.

Malarial Fever.

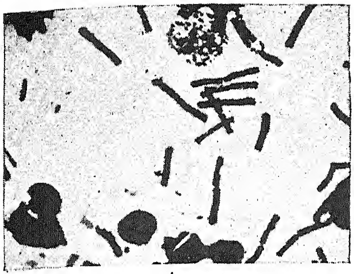
Malaria is one of the most widely prevalent of all infectious diseases, and few infections compare with it in the total number of fatalities. In distribution, malaria extends from the arctic circle to the equator, but is most severe in warm climates. Malaria is a preventable disease and

has been practically stamped out in some countries. In the last half century it has greatly diminished in the United States; it is now rare in the northeastern part of this country, but it still exists in some regions of the south, although with much less than its former prevalence. The fevers common in the tropics are largely malarial. This disease is the greatest obstacle to settlement by the white man along the rivers and coasts of tropical countries.

Malarial fever is caused by a microscopic animal parasite or plasmodium. This parasite lives primarily in one variety of mosquito, the Anopheles. It is transmitted to man by the bite of the mosquito; it uses him as an intermediary host or stepping stone to reach other mosquitoes, which in turn are infected by biting the man. So far as known, the plasmodium does not impair the health of the mosquito.

In man the malarial parasite enters and multiplies within the red corpuscles of the blood. The symptoms of the disease accompany the disintegration of these cells as the parasites are discharged from them. The attack commences with a chill. In severe cases the sufferer shivers so violently that the teeth chatter and the whole body shakes. The chill lasts from a few minutes to an hour or even longer. Although the skin is cold, the temperature of the body rises rapidly during the chill and may go as high as 104° F. Following the chill, the blood vessels of the surface relax and the skin becomes hot, red and dry, although the temperature of the body does not usually increase beyond the temperature attained during the chill. This hot stage is often accompanied by a violent headache and intense thirst. In a half hour to three or four hours perspiration appears, and the headache and acute discomfort pass off for some hours or days.

The paroxysms of malaria occur at intervals which depend upon the time required for the cycle of development of the parasite in the red corpuscles. In one type, tertian fever, the symptoms occur every three days; in another type, quartian fever, they occur every fourth day and are usually milder than in the tertian type. Double or even triple infection may occur, so that parasites appear in the blood each day, and with daily paroxysms. There is a third type of malaria in which the symptoms are irregular and in which the fever may be either intermittent or continuous. In temperate climates malaria is not often fatal, but in tropical countries severe forms of the disease occur and the death rate is high. These severe fevers are usually of the irregular or continuous type. The destruction of the red corpuscles may be so extensive that



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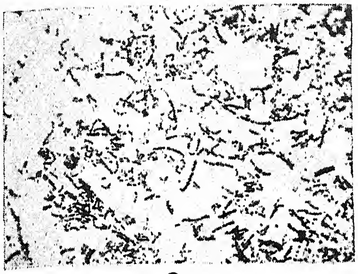

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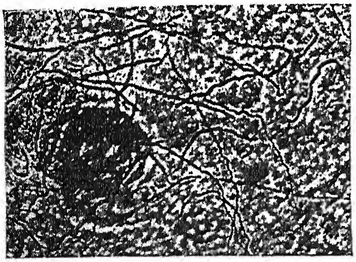

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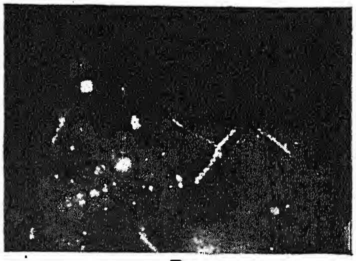

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PLATE VIII. PARASITIC ORGANISMS.

(A) Anthrax bacilli from the spleen of an animal which died from the infection. See page 309. The bacilli are rod-shaped; the larger oval structures are tissue cells and blood corpuscles.

(B) Meningococci in spinal fluid withdrawn from a child suffering from epidemic meningitis. See page 348. The large grouped particles are the nuclei of white blood cells. See page 348.

(C) Diphtheria bacilli in material taken from the throat of a child with diphtheria. See page 189.

(D) Bacilli and spirilla found in material taken from the sores caused by Vincent's angina or trench mouth. See page 26.

(E) Fungi in scrapings of skin of the feet from a case of ringworm. See page 312. The fungi are the dark thread-like structures; the lighter material is epithelial cells. Ringworm may be caused by many forms of fungi other than those shown.

(F) The organism of syphilis in material taken from a primary sore. See page 564. In the five other specimens on this page the organisms have been rendered visible by staining them with dyes. The organism of syphilis is stained with difficulty and is made visible under the microscope by dark stage illumination, that is, by using a dark background and passing the light at right angles to the line of vision. The organisms appear as white spirals.

the urine is colored with hemoglobin or its products, giving rise to the name "black-water fever."

Quinine, an alkaloid derived from the bark of the cinchona tree, a native of South America, kills the malaria plasmodium within the blood but not during the time it is in the red cells. Large doses cause an unpleasant ringing in the ears, and blindness occasionally results from its excessive use. Some persons are particularly susceptible to the drug. In malarial regions quinine may be taken daily in amounts from 5 to 10 grains as a prophylaxis against the disease. The quinine does not always prevent infection, but it usually prevents any severe symptoms of the disease from developing.

Yellow Fever.

Yellow fever, like malaria, is transmitted by a mosquito, not the Anopheles, but one known as Aedes aegypti. This mosquito is not as widely distributed as the malarial mosquito. Yellow fever is primarily a disease of the tropics and subtropics. Before the means of spread and hence means of control were discovered, yellow fever occasionally, but only in the summertime, was carried as far north as Boston. In the late eighteenth century Philadelphia and New York suffered from devastating epidemics. The disease-bearing mosquitoes were carried to these parts in the open water tanks of wooden sailing vessels coming from the tropics. Today yellow fever is limited to certain regions of South America and the western coast of Africa. Conditions in India are favorable for the spread of the disease, but fortunately it has not been carried to this region.

Yellow fever starts abruptly; there is intense headache and muscular pain, with extreme prostration and high fever. On the second or third day the disease decreases in severity. In mild cases it may cease at this point, but in most instances after a remission of a day a second period of illness starts, more severe than the first. It is in this stage that the jaundice which gives the disease the name yellow fever appears. The capillary blood vessels are weakened and there may be hemorrhage from the gums, stomach and bowels, and under the skin. The mortality averages about 20 per cent; it is much lower for children.

Yellow fever is caused by a filterable virus; the infective agent, like the malarial parasite, does not appear in the secretions of the body, so that the disease cannot be transmitted by contact, but only by inoculation. Furthermore, the active agent can be obtained from the blood only during the first three days of the disease. A period of twelve days

elapses between the time the mosquito has ingested the blood and the time that it can transmit the disease. The mosquito may live for a considerable time thereafter and inoculate many persons.

The control of yellow fever depends upon the isolation from mosquitoes of those who are ill to prevent the infection of the insects, and upon the eradication of the mosquitoes. The anti-mosquito measures against the Aedes aegypti are essentially the same as those employed against the Anopheles, but with one difference: the Anopheles breeds largely in marshes, swamps, and woodlands, and is not primarily a domestic mosquito. The Aedes is thoroughly domestic. Its range of flight is short. It breeds about houses, in any small deposit of water. The measures of eradication, therefore, depend upon the screening or removal of every such collection rather than the drainage and oiling of swamps and pools in the countryside. The city of Havana, which for 130 years had been continuously infested with yellow fever, was cleared of the yellow fever mosquito in 1901. Quinine is not a prophylactic against yellow fever.

Rocky Mountain Spotted Fever.

Rocky Mountain spotted fever is a disease caused by a Rickettsia (see typhus fever) occurring in wild rodents and transmitted from them to man by ticks. The disease was first observed in Idaho and the Bitter Root Valley of Montana, but is now known to occur also in California, Colorado, Oregon, Nevada, Washington, Wyoming and the Dakotas. Occasional cases develop in the eastern states. Rocky Mountain fever occurs only in limited areas and for a short season of the year, early spring to the middle of July, the period in which the adult ticks are active. The disease occurs mainly among foresters, hunters, fishermen, sheepherders, cowboys and surveyors, since it is they who are most apt to go into the infested rural regions.

Rocky Mountain fever closely resembles typhus fever; indeed, it may be a variety of this disease. There is first a day or two of ill-defined discomfort and slight illness; the severe symptoms then start abruptly with a chill and high fever. The rash from which the disease gets the name spotted fever develops on the third to the seventh day. The fever remains high for seven to ten days and then, in favorable cases, subsides slowly. The mortality varies greatly in different regions; in Colorado the disease is usually non-fatal; in Idaho it has a mortality of about 5 per cent, and in Montana it has risen as high as 76 per cent. A protective vaccine is prepared from infected ticks.

Psittacosis.

Psittacosis is a highly infectious disease usually transmitted to man from infected parrots. The infective agent, probably a virus, appears in the feces and the nasal secretions of the bird. Handling a sick parrot or inhaling the dust from its cage is the usual mode of transmission. The symptoms of the disease resemble somewhat those of typhoid fever, but usually bronchopneumonia develops. The mortality may be as high as 30 per cent. The disease is rarely fatal in those under the age of twenty.

Tularemia.

Tularemia is primarily a disease of rodents, especially rabbits, but may infest nearly all other animals including man. The organism of the disease, the bacterium tulareuse, can be carried by almost any biting insect; man is most commonly infected by the deer fly. In addition to insect transmission, the disease can be acquired directly by skinning, or even handling, an infected animal. The disease occurs most commonly among butchers who prepare rabbits for market; many cases have also developed in hunters. Wild rabbits that are sluggish, easily caught, are sick rabbits, and should never be touched with the ungloved hand. This same warning applies to a dead rabbit found in the field. The bacillus tulareuse can apparently penetrate the unbroken skin; cooking kills it.

Tularemia is mainly a disease of the United States; cases have occurred in every region of the country except the New England States and Washington. In the majority of cases of tularemia an ulcerous sore develops at the point on the skin where infection occurs. The lymph nodes draining the region become enlarged and painful. There is fever and prostration. The disease is rarely fatal, but the illness it causes may persist for several weeks. In some cases the infective agent enters the eye from rubbing it with contaminated fingers. In still other cases the local sore which usually marks the site of entry of the organism does not appear.

It has only been a few years since tularemia was discovered and defined as a definite disease. Probably many more cases occur than are recognized. The disease is not infectious from one human being to another by contact; it does not occur in epidemics. Moreover, there are no striking characteristics that lead to immediate recognition. A delicate serological test has been developed which affords a positive method of diagnosis. The reaction to this test persists after recovery from the

disease. Its application to large groups of individuals shows that many cases of tularemia have been mistakenly diagnosed as other diseases such as influenza.

Scabies, or Itch.

Scabies, or "the itch," is a distressing skin eruption caused by an almost invisibly small insect or, more correctly, a mite. The male inhabits only the surface of the skin. The female excavates oblique tunnels, usually on the wrist and between the fingers; in these she lays the eggs from which the larval parasites hatch. The bite of the itch mite produces a small red spot; the tunnel made by the female appears as an elevated more or less zigzag line, often infected and filled with pus. Both types of sores itch intensely, especially at night.

Scabies is usually transmitted only by closest personal contact. The disease is easily cured; for this purpose the dermatologist uses ointments or lotions containing sulphur, a substance highly toxic to the itch mite. Without treatment, scabies persists indefinitely.

In addition to the itch mite there are a number of others that occasionally prey on man, but only as temporary parasites. "Grain itch" is caused by a mite that has its normal habitat on straw where it is a parasite of insects. It will attack the human skin; its bite produces a raised red area resembling the eruption in hives. Infestation occurs among those who handle straw or sleep on new straw mattresses. In severe cases there may be fever.

Rat mites which infest brown rats may occasionally attack man. The bites appear in groups of six or more, usually on the legs. Any place infested by rats may harbor the mites. They are temporary parasites.

The harvest bug, or harvest jigger, lives on grasses and bushes; the adult is harmless, but the minute larvae burrow into the skin, producing welts that may last for several days. The intense itching begins a few hours after walking through the field of shrubbery infested by the parasite. Although the name jigger is often used for this mite, this term is correctly applied only to the burrowing sand fleas of the tropics, the true jigger or Chigoe.

Hydrophobia.

The wounds caused by the bites of dogs, cats, and other animals are essentially like ordinary lacerated wounds and are easily contaminated. Such wounds usually heal without complications if they are carefully

cleaned and dressed. But there is a special danger from the bite of animals in the possibility that the virus of hydrophobia or rabies may be inoculated. Hydrophobia is a disease to which all warm-blooded animals are susceptible. The virus is present in the saliva and is transmitted only by inoculation. This inoculation is usually effected by the bite of the animal, but may occur from entrance of the saliva into a scratch in the skin. Thus rabies occasionally results from merely handling the diseased animals or being licked by them. The disease is usually transmitted to man by the dog; less commonly by the cat, wolf, skunk, and other animals; in some tropical regions it is carried by bats. There is no authentic case of the transmission of the disease by man, although this may be possible.

The length of time elapsing between the inoculation and the development of the disease ranges for man from two weeks to three months. The incubation period is shorter in children than in adults, and shorter from wounds about the face than from wounds in the extremities. Rabies is a disease of the nervous system; the virus travels along the nerves to the spinal cord and brain and not through the blood. In man rabies usually starts with itching and tingling sensations in the site of the wound where the infection entered. General illness then follows and passes into a stage of intense excitement, delirium and convulsions. Any attempt to drink water is followed by a spasm of the larynx which is so extremely painful that the sufferer dreads the sight of water; hence the name hydrophobia. The excitement and spasm last for two or three days. Paralysis and unconsciousness then develop; death follows usually within a day.

In the dog rabies may appear in either of two forms, the furious or mad, and the paralytic or dumb, rabies. The furious is by far the more common. The animal is at first restless, but without showing any particular tendency to bite; it attempts to hide. Soon, however, comparable to the excitement stage of the disease in man, the dog becomes furious, often running wild and attacking men, animals, and even inanimate objects in its path. Finally it falls exhausted and partially paralyzed; it becomes unconscious and dies.

In the dumb form of rabies the dog becomes paralyzed without showing the stage of excitement. It often appears to have a bone stuck in its throat. Kindly intended efforts to remove the presumed obstruction have often led to infection. The saliva of a dog may be infective for three or four days before the animal shows any symptoms of disease.

Contrary to general belief, rabies does not occur exclusively in hot

weather; temperature has no influence upon the disease, and the fact that cases may be particularly prevalent during warm weather is due to the circumstance that dogs roam more freely then.

A bite by an animal should always be treated immediately, and by a physician if possible. The treatment consists of opening the wound and promoting free bleeding. Every part of the wound should be cauterized with fuming nitric acid. The animal inflicting the wound should be captured alive if possible, and kept in captivity. If the animal dies within the next week, preventive inoculation should be administered to the person bitten, no matter how thorough the cauterization has been. If the animal survives, there is reasonable assurance that it was not suffering from rabies. If it was shot instead of being captured alive, the head should be sent to the state laboratory for diagnosis as to rabies. If the animal escapes, and there is any suspicion of rabies, a prophylactic treatment is advisable. Once established, rabies is hopelessly incurable; therefore no precaution should be omitted in its prophylaxis.

The preventive inoculation for rabies was developed by Pasteur in 1883. When the virus obtained from a mad dog is injected into a rabbit, the disease occurs in the rabbit after an incubation period of fourteen to twenty-one days. The virus is then taken from the spinal cord of the rabbit and transmitted through a series of rabbits. In this transmission the virus is altered. It becomes much more virulent for rabbits, so that the disease develops on the sixth or seventh day, and death follows on the ninth or tenth. But at the same time the virulence for man decreases. When the virus has been raised to its point of highest virulence for rabbits, the infected animals are killed and their spinal cords removed. This nervous tissue contains the modified virus in abundance. It is dried and ground into glycerin or other preservative agents. The injection of increasing doses of the vaccine thus produced renders the human recipient immune to rabies. The immunity appears two weeks after the treatment and lasts at least two years.

The prophylactic treatment is highly effective. In New York (1930), of 7402 treated cases, 3057 of which were known to have been bitten by rabid animals, the mortality was 0.16 of one per cent. Before the introduction of the Pasteur treatment the mortality under such circumstances would have averaged about 16 per cent.

Rat-bite fever.

Rat-bite fever is an infection caused by a spiral-shaped microorganism transmitted by the bite of the rat. The disease is more com-

mon in the Orient than elsewhere, but cases have occurred in the United States. The great majority of rat bites lead to no ill effects except possible local infection. The bite of the animal carrying the organism of rat-bite fever heals as rapidly as that of a non-infective animal, but after a period of from one to three weeks the scar becomes red, swollen and painful; sometimes an ulcer forms. Illness, chills and fever follow. After two or three days the fever subsides, but after a lapse of five or six days rises again in a second attack. If the disease is allowed to run, the attacks continue to recur. The salvarsan used to treat syphilis acts as a specific cure for rat-bite fever.

Snake Bites.

All of the poisonous snakes of North America, with one exception, belong to the class of *viperidae* or vipers. The exception is the coral snake found in the southern states. The vipers are characterized by erectile fangs. The jawbone to which the fangs are attached is jointed in such a manner that it rotates when the snake strikes, thus causing the fangs to project straight forward. These fangs are pointed at the end and have a central canal like a hypodermic needle. Poison is forced through them by a muscle which contracts upon the poison gland at their base. The poisonous vipers include the rattlesnakes, of which there are more than a dozen species, the copperhead adder, and the water moccasin. In the poisonous snakes belonging to the class *colubridae*, the fangs do not project forward when the snake strikes. To this class belong the coral snake of North America, the cobras and numerous other snakes of India and of Australia.

The main toxic agent in the venom of vipers acts primarily upon the blood; that in the venom of the *colubridae* acts upon the nervous system. The flesh in the region of snake bites is seriously damaged by the venom, particularly by that of vipers. The wounds are readily infected with bacteria, and they heal poorly. In poisoning by vipers the general symptoms that develop are great prostration, with cold sweat, feeble pulse, and vomiting. In poisoning by the *colubridae*, drowsiness and paralysis develop. The seriousness of snake bite depends upon many factors—the species, the size of the snake and of the individual bitten, the warmth or coldness of the weather and how long a time has elapsed since the previous discharge of venom. Few fatalities result from copperhead poisoning, and those mainly in children; rattlesnake bite has a mortality of 12 to 20 per cent.

To be effective, treatment of snake bite must be immediate. The most important step is to apply a tourniquet between the injury and

the heart. Most bites are on the extremities and the tourniquet can be placed on the upper arm or thigh. It should be loosened for a few seconds each twenty minutes. The next step is to cut into the flesh at the site of the bite, going to the full depth of the fangs; the wound is then sucked, preferably with a small pump designed for this purpose. The most important general step is to administer anti-venom serum. This serum can usually be purchased in regions where snake bites are apt to occur. Permanganate and similar oxidizing and cauterizing agents should not be applied to the wound. They do little good in destroying the poison, and much harm to the flesh about the wound. Alcohol, contrary to popular belief, is of no benefit whatever in the treatment of snake bite.

Stinging and Biting Insects.

There are numerous insects which puncture the skin and inject irritating and poisonous substances. These insects use their stings as weapons of defense and are not blood-sucking. Scorpions, spiders, centipedes, bees, wasps and hornets are the most common of these stinging insects.

The poison of the scorpion is secreted in glands in the last segment of the abdomen; the shell of this segment is pointed and forms the sting through which the poison is discharged. The venom of the scorpion is said to be more potent than that of a cobra. It is secreted in relatively small amounts, however, so that fatal poisoning by the scorpion is rare in adults, although the sting of the larger variety may be fatal in children. The local effects of the sting are severe. There is intense pain and inflammation about the wound. The flesh often dies in the inflamed areas and readily becomes infected. The sting of a scorpion should receive the same local treatment as a snake bite.

The poison apparatus of the spider consists of two long pouches lying in the thorax and extending into the jaws from which the poison is discharged. Some of the larger spiders, or tarantulas, found in Russia, Italy, and tropical countries, cause severe poisoning. The poison resembles snake venom, but the quantity injected is small. In the United States the only spider causing severe poisoning is the so-called "black widow." This spider occurs mainly in the south, but is occasionally found as far north as New Hampshire. The female spider is large, with a leg spread that may be as great as two inches; the male is smaller and does not bite. The body of the spider is black and globular and is usually marked with a red patch shaped like an hourglass. The insect usually inhabits dark places, particularly country privies

where it spins its web under the seat. Most bites occur at night and are upon the genitalia of men.

The bite causes only a slight wound, but results in intense pain. Little can be done in the way of first-aid treatment except to put warm applications over the painful region and give black coffee. The mortality is said to be about 8 per cent.

The sting of the bee, wasp or hornet usually results in nothing more serious than local pain and swelling; relief is given by removing the sting if it is in the wound and applying carbolated vaseline. Occasionally, however, the sting may cause serious illness or even death. These severe effects result when: (1) the individual is stung at one time by many insects; (2) when he is allergic to insect venom; and (3) when he is stung in the mouth. The sting in the mouth which may occur while eating fruit holding a wasp or bee results in rapid swelling of the tongue and throat, occasionally so severe as to cause strangulation.

CHAPTER XIV

THE NERVOUS SYSTEM, ITS SERVICE AND FAILURES

Integrative Action of the Nervous System.

In Chapter I it was pointed out that the individual cells which compose the human body differ in no fundamental property from the most elementary unicellular organisms. The body is an aggregation of cells. The scope of man's activities is far wider than that possible from a group of independent cells. This wide range of activities results from the cooperation of the cells in working toward common objectives. This cooperation necessitates a system of communication and regulation. It is supplied by the nervous system, which consists of the nerves, the spinal cord and the brain.

The unicellular organism when stimulated by some force from its environment responds, and in a manner characteristic of the organism. The ameba contracts from the touch of a needle point but surrounds a particle of food. Similarly the cells of the human body respond when stimulated, each according to its specialized nature; a muscle cell contracts and a gland cell secretes. Stimulation is necessary for activity. In the body, however, only a small portion of the total number of cells is in contact with the environment and so in a position to be receptive to direct stimulation. The remainder (and those near the surface as well) depend for the stimulation which initiates and controls their activity upon impulses brought to them in nerves.

The nerves run to and from the spinal cord and brain connecting all parts of the body with the nerve centers. In one type of nerves, called sensory or afferent, impulses are aroused by forces, stimuli, acting upon the far ends of the nerves. The stimuli which arouse the impulses may come from within the body as a result of the activity of one of its parts; or they may be on the outside acting upon one of the organs of sense, such as that of sight. The afferent nerves do not carry their impulses directly to the tissues to be stimulated or regulated; instead, they carry them to the spinal cord or brain. The impulses they bring there are then relayed, transmitted, outward along nerves, called motor or efferent nerves, which extend to all parts of the body; impulses

traveling in the efferent nerves stimulate the cells of the body and regulate their activities. The cord and brain, standing as they do between the source of stimulation and the point of response, exercise a controlling influence over the relaying of the impulses. Consequently all efferent impulses, and hence all activities of the body, are integrated in relation to all afferent impulses and therefore to all conditions in and about the body. It is this integration that makes it possible for the body to act as a whole and to act purposefully.

The Reflex.

The whole process of stimulation and response in which an impulse is aroused in an afferent nerve and transmitted into an efferent nerve is termed a reflex. Some reflexes are simple in the connections made for the relaying of the impulse; others are exceedingly complicated, as in complex and apparently voluntary acts. The pathways and central connections for some of the reflexes are established before birth; others develop soon after and are the same in all individuals. These intrinsic or "unconditioned" reflexes are involved in such wholly automatic and unconscious acts as the secretion of saliva when food is put into the mouth, or the involuntary withdrawal of the hand from the touch of a hot object. The pathways and central connections for other reflexes are developed through experience and may therefore be different in different individuals; they are called acquired or "conditioned" reflexes. This type of reflex involves consciousness in its development, although later it may appear almost instinctive. The secretion of saliva as the result of hearing the dinner bell is a reflex of this type. The reactions made by man to his surroundings and toward other men, which appear to him to be voluntary, are largely determined by his acquired reflexes. The variety of acts which may result from the reflexes and the intricacy of the acts is due to the almost infinite connections and combinations of connections made in the cord and brain from the transmission of afferent impulses as efferent impulses.

Impulses coming into the higher centers in the brain give rise to a modification of consciousness known as perception. When a man puts his hand on a hot stove, an unconditioned reflex causes the immediate withdrawal of his hand; at the same time he perceives that he has burnt himself and that he has moved his arm. Similarly the eyelids wink involuntarily when the eyeball is touched, and the leg moves when the tendon at the knee is tapped. Consciousness of the fact that the hand has been burnt, the eye touched, or the knee tapped is not

necessary for the accomplishment of the act. Unless the nervous system were profoundly injured or depressed his hand would jerk away, his eyelids would wink and his leg move, even if he did not will to do so and were indeed unconscious of the act. This is seen best when a frog, whose brain and all consciousness have been destroyed but its spinal cord left intact, wipes a drop of acid off its leg. The connections for this intrinsic reflex are made in the cord; if the cord is destroyed the reflex no longer occurs.

The Nervous System and Human Behavior.

The working of the nervous system is illustrated in every act. For example, a man sees an object on the ground. The impulses transmitted through sensory nerves from the eyes to the brain give rise to this perception. The man's subsequent behavior, his reaction to the particular circumstances, is then determined by the sum of his intrinsic and acquired reflexes. If the object is for him neither desirable nor dangerous, he ignores it. If it is offensive, he avoids it. If it is desirable he picks it up. Which of the three reactions he will make seems to him to depend upon the ideas which the sight of the object induces in his brain. But in reality animals which have practically no ideas, such as butterflies, go toward objects that stimulate them attractively, and avoid objects that stimulate them repulsively. In such reactions consciousness is a sort of artifact, and the man merely rationalizes his own almost automatic behavior. His nervous system being what it is, he could not have acted otherwise.

The perception of the object on the ground sets in train a series of responses on the part of the man. Impulses are sent to certain muscles of the body and they become active. At the same time the muscles which might oppose the active muscles remain relaxed; their contraction is inhibited. The man leans over and extends his arm toward the object. While the act is being carried out, impulses travel up sensory nerves, bearing information as to the extent of the movement of the muscles and as to the shape, texture and temperature of the object touched. At the same time sensory nerves from the organ of equilibrium, the semicircular canals of the inner ear, bring to the brain subconscious information as to the position of the body. These impulses originate others, which automatically make the needed connections in the brain and spinal cord, so that impulses go out through motor nerves to muscles not directly engaged in the act of picking up the

object. These muscles move various parts of the body in such a manner as to compensate for the movements of other parts in the opposite direction, so that balance is maintained. The integration of activities extends further and includes the function of the internal organs; breathing and the circulation are both altered during the movement of the body. If the movement is vigorous or prolonged, both of these functions are augmented.

An act apparently as simple as stooping to pick up an object is in reality enormously complex. It is only through the integrative activity of the nervous system that it can be accomplished. The accurate working of this integration is in part inherent in the very structure of the central nervous system, which affords, therefore, certain patterns of response identical in all men, because they are characteristic of the structure of man; animals of other species may have other responses to the same stimuli. In part, certain patterns of response are developed by experience and particularly by education. A man does not play the piano except after developing the necessary pattern of successive momentary, nervous connections. We speak of voluntary acts, but most of man's acts have been repeated until they are nearly as automatic as those which are inherent and instinctive.

The Neurone.

The unit of the nervous system is the nerve cell, or neurone. Each neurone consists of a cell body, like that of other cells, but with a hair-like process called a nerve fiber or axone extending from it. Some nerve fibers attain a length of three feet or more. When many nerve fibers extending from one section of the body run in a bundle, like the wires of a telephone cable, and are surrounded by a sheath of connective tissue, the structure thus formed is called a nerve. The sciatic nerve which runs down the leg, and which is as thick as the little finger, contains thousands of nerve fibers; some are motor, some are sensory, and some are the so-called autonomic fibers to be discussed later. The tip of each nerve fiber is connected with the structure to which or from which it carries impulses, a muscle fiber or a sensory organ.

Besides the main nerve fibers, or axones, many shorter processes may extend like rootlets from the body of the neurone. These are called dendrites. The connections for the transmission of impulses between neurones are made by contact between the nerve fiber of one neurone

and the dendrites of the next, or through the dendrites of two or more neurones. The points where the dendrites thus interlace and make contact are known as synapses. The dendrites of an afferent neurone may have synapses with the dendrites of many efferent neurones, so that an impulse arising from any part of the body may be transmitted to several structures simultaneously, and may cause their cooperative action in a definite pattern of response elicited only by that particular stimulus. Such connections between neurones occur only in the so-called gray matter of the spinal cord and brain where the nerve cells lie.

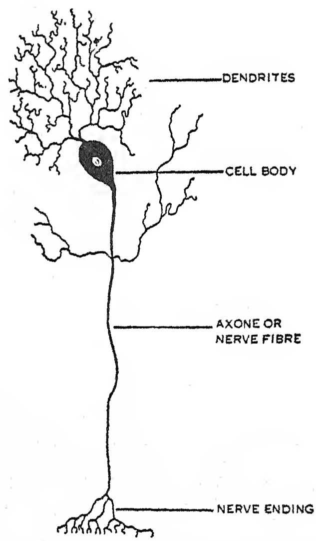

Figure 48. NEURONE.

The substance of the cord and also of the brain is made up largely of nerve fibers which run from one part of the brain to another, or to the cord, and form the pathways of communication. The fibers constitute what is known as the white matter. In addition to these fibers there are, within the substance of the cord and brain and upon the surface of the latter, masses of nerve cells and dendrites through which the connections are established between fibers for reflexes. These nerve cells and their dendrites make up the gray matter of the brain and cord. Certain of these masses have special control over the functions of particular organs. They are often called nerve centers. Thus there is a respiratory center which is concerned with the control of respiration.

The Nerve Impulse.

The impulse which travels over a nerve fiber is neither a wave of physical movement as is sound, nor is it an electric current, although some of the energy used for the impulse is dissipated as electricity and can be detected and measured with a sensitive galvanometer (see electrocardiograph, page 166). The nerve impulse is generated in the nerve fiber, and the energy for its propagation is derived from food materials in the fiber through which it passes. The movement of the impulse is analogous to the passage of a flame along a train of gunpowder; the impulse, unlike the electric current which diminishes with the resistance of its conductor, is as strong when it reaches the brain as when it started; it maintains its strength unchanged when relayed from afferent to efferent nerves. The speed at which nerve impulses travel is much less than that of electricity or even sound. The velocity varies in different nerves, but probably does not greatly exceed 100 meters a second.

The nerve impulse is not continuous like the flow of electric current from a battery, but is of very short duration. For an even shorter time following the impulse the nerve is incapable of transmitting another impulse; it has, like the heart, a brief refractory period. If the stimulation of the nerve is continued, a second impulse follows the refractory period, and it in turn is followed by another refractory period, and then by an impulse and so on. The result is the development of a series of impulses not unlike "dots" sent out along a wire by a telegraph key. The frequency of the impulses depends both upon the nerve carrying them and upon the intensity of the stimulus arousing them. There may be as few as twenty a second, or as many as several hundred.

All impulses in a nerve are of the same strength, regardless of the intensity of the stimulus eliciting them. If the force applied to a nerve, as in touching the skin, is very small, no impulse is aroused; if the force is increased, a point is reached at which the impulse is aroused and aroused at once in full strength; further increase in the intensity of the applied force does not increase the strength of the impulse. The fact that the sensation aroused by pressure applied to the skin can be felt to vary with the pressure is due, not to any variation in the impulse strength in the nerve fibers, but to the frequency of impulses and to the greater or lesser number of fibers in which the impulse is aroused by the pressure during its variations.

How Sensations Are Received and Interpreted.

The perception of any sensation, such as sight, hearing, touch or taste, depends upon the action of three structures in succession: first, the receptive organ upon which the source of energy (light, sound, etc.) acts, initiating the sensation; second, the nerve which leads from the receptive structure to the brain; and third, the particular area of the brain to which this nerve is connected and from which we draw the consciousness of sensation.

The energy acting upon the receptive structures arouses a nerve impulse. The receptive structures are specialized, so that each type responds to only one form of energy: in the ear to sound, in the eye to light, and so on. In the skin there are several distinct senses—heat, cold, touch, pressure, and others—each with its own specialized and selective type of receptive organs. But there is only one kind of nervous impulse for all.

The nervous impulse started in the receptive structure is transmitted through the nerves which lead to the brain either directly, as in the case of those from the eye and ear, or indirectly by way of the spinal cord, as in the case of those from the skin. The nerves connect with different areas of the brain. When an impulse comes in on any nerve to its particular brain area, we feel in some definite portion of our skin, or hear or see according to the type of receptive sensation which characterizes that particular area of the brain. The sensation is not, however, referred to the brain, where alone it exists as a modification of consciousness, but is projected outward to the source of stimulation. Thus we refer a sensation of touch to something just outside the skin; taste, not to the tongue but to the contents of the mouth; sight, not even to the eye, but to the outer world, perhaps to an object across the street or in the sky.

Since there is only one form of nerve impulse, irrespective of the source, it follows that the sensation aroused in the brain is determined solely by the particular nerve affected. A striking example of this is afforded by the eye. If the nerve leading from the eye to the brain is jarred or otherwise irritated mechanically, impulses are aroused in the nerve and these are perceived as flashes of light. This is the explanation of the "stars" seen from a blow on the eye. The phenomenon can occur in a totally dark room and "light" is thus seen where none exists. A disagreeable experience arising from a like cause is common to those who have lost a leg or arm; they may suffer pain in the missing fingers or toes. This effect arises from the excitation of the severed

nerves in the stump, but it is referred by the brain to the positions formerly occupied by the missing members. In much milder form the same sensations are experienced when a nerve, such as the "crazy bone" of the elbow, is struck; the fingers, from which fibers of this nerve normally bring sensations, tingle. When an arm or leg "goes to sleep" the disturbance arises from pressure upon a nerve as in crossing the legs; the sensation is not experienced at the point of pressure, but is referred to the area supplied by the nerve.

Still another type of disturbance may occur in the system by which sensation is received and interpreted. From some intrinsic cause the brain may become excited and record sensations which are not occasioned by any impulse arising from external sources of energy. Thus in fever, mental disease, poisoning or intoxication, there may be visual or auditory hallucinations. The individual apparently "sees" objects or animals which in reality are not before him. Thus are occasioned the "snakes" seen by the acute alcoholic, and the "voices" heard by the insane.

Intensity of Sensation.

In order to arouse a sensation, not only must energy be applied to the receptive organ of the particular sense, but the amount of energy must exceed a certain lower limit. Thus in relation to sound, the tick of a clock which cannot be heard at thirty feet may be audible at sixteen feet. At the shorter distance the energy of the air waves is sufficient to arouse the sensation of sound; at greater distances the energy is insufficient. The lower limit of energy necessary to arouse any sense is known as its "threshold value." The threshold value for any sense is different for different persons. For hearing it ranges all the way from unusual acuity to complete deafness. Furthermore, the threshold value varies greatly with the state of attention. A person engrossed in deep thought may be unconscious of external happenings.

As the amount of energy exciting the senses is increased above the minimal or threshold value, the sensation is increased also. But while the energy may be increased indefinitely, the intensity of the sensation never exceeds a certain upper limit or maximum. The application of energy above the maximum produces no increase in the sensation, but causes fatigue and exhaustion of the receptive apparatus. A very brilliant light shining in the eyes results in temporary blindness; and loud sounds are followed by a period of deafness. If the eye is first fatigued

by looking at a red object, a white object then for a short time appears green.

Between the threshold and maximal values for any sense, variations in the intensity of the sensation are perceptible. The delicacy with which these changes can be perceived depends, not upon their absolute, but upon their relative, amounts. If a one-ounce weight is held in the hand, the addition of a second, a third, or even a fourth ounce is readily appreciated. But the addition of one ounce or even four ounces to an initial load of forty pounds would not be felt. The amount that any stimulus must be increased in order to be perceptible is a nearly uniform percentage for all intensities between the minimum and maximum. Thus, if to a weight of twenty ounces held in the hand, one ounce must be added to cause an appreciable difference, then for a load of forty ounces the same ratio is maintained and two ounces must be added; while to ten pounds a half pound must be added, and so on.

This fundamental principle, called Weber's law, applies with reasonable limits to all of the senses. We cannot see the stars in the daytime because the amount of light that they contribute to the illumination of the heavens is too small a percentage of the total to be perceptible. With the setting of the sun the percentage of illumination furnished by the stars is increased, although the stars are themselves no brighter; they then come into sight in the darkening sky in the order of their brilliancy; faint stars are seen only when there is no moon. The same principle applies to the so-called "glare" of the headlights of an automobile; it may prevent our seeing objects otherwise visible.

Adaptation.

If the stimulation applied to a receptive organ is prolonged it eventually ceases to arouse sensations. This phenomenon is spoken of as adaptation; we "become accustomed" to stimuli. Thus if a ring is put on the finger the wearer is at first acutely conscious of it, but after a time he becomes wholly unaware of its presence; likewise we are not conscious of the contact of our clothing. The sense of smell quickly adapts itself to persistent stimuli; one cannot smell his own breath when it is foul, or, after a short time, perfume upon his clothing, although the odor of both may be instantly apparent to anyone meeting him. The foulness of the air in a poorly ventilated and smoky room is strikingly evident on entering, but the sensation disappears on staying in the room. A bath feels much hotter on first entering it than after being in it for a time; and the tick of a clock in the room or the sound

of traffic from the outside soon ceases to be heard. A moving object is more readily perceived by the eye than a stationary one, and when vision is concentrated on an object the eyeballs are constantly moved slightly in order to stimulate new areas of the retina so that vision is not lost by adaptation.

The Spinal Cord.

The spinal cord and brain together are known as the central nervous system. The brain is inclosed in the skull; the spinal cord extends

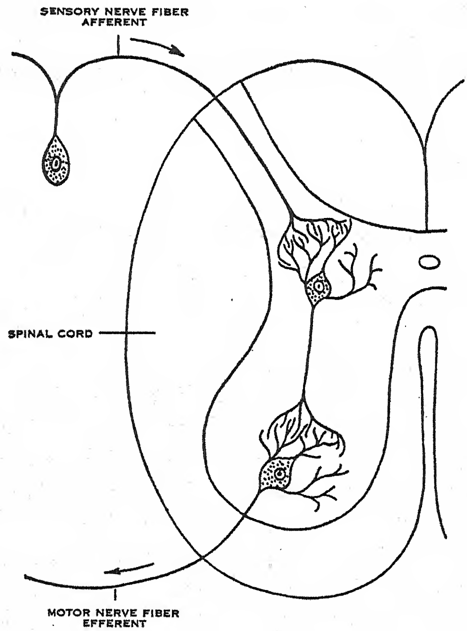

Figure 49. Schema of Cross Section of Spinal Cord.

through the canal within the vertebrae. It is about eighteen inches long. All the nerves of the body, with the exception of twelve pairs which connect directly with the brain, enter or leave the spinal cord. The sensory nerve fibers, in groups called spinal roots, enter on each side of the rear of the cord; the motor fibers similarly emerge from the front of the cord. A short distance from the cord the spinal roots from each side unite and are inclosed by a sheath to form nerve trunks which pass between the vertebrae. The cell bodies of the neurones

which supply the fibers of the sensory nerves are located outside of the cord in enlargements, or ganglia, upon the sensory spinal roots. The cell bodies of the neurones that supply the fibers for the motor nerves are located within the gray matter of the cord.

The twelve pairs of nerves which arise from the lower part of the brain and emerge from the skull are known as the cranial nerves. They supply the eyes, ears, nose, and the muscles and skin about the head. The vagus nerves are also of this type, but after emerging from the skull they extend down the neck and into the chest and abdomen, sending fibers to the visceral organs. The vagus nerve has been mentioned previously in its (efferent) function of controlling the rate at which the heart beats and in its (afferent) function of regulating breathing; it also influences the motility and secretion of the alimentary tract.

The Medulla.

The spinal cord on entering the skull continues its course for a few inches and is known, in this locality, as the brain stem. This stem divides above into two divergent arms which extend into the mass of the cerebrum. The first portion of the brain stem, the spinal bulb, or medulla oblongata, resembles the cord except that it is of somewhat greater diameter and complexity of structure. In it are located the centers controlling breathing and also those which control the tonicity of the blood vessels, the rate of the heartbeat, and similar important activities. The medulla, while functioning chiefly below the level of consciousness, thought and voluntary motions, nevertheless assists in the control of the basic or "vegetative" functions of the body, those functions in which all vertebrates are essentially alike. Damage to the medulla leads to death through cessation of breathing; fortunately it is well protected from external injury by its situation at the base of the skull.

The Cerebellum.

Directly above the medulla the brain stem bulges still further to include a band of nerve fibers extending laterally across it. This band of fibers is called the "pons," or bridge, and connects the two sides of a mass of nerve tissue, white matter within and gray matter on the surface, known collectively as the cerebellum. The cerebellum is approximately the size of the clenched fist; it is located back of the medulla. The function of the cerebellum is imperfectly understood;

but it is known to play an important part in the coordination of muscular movements. While the more conscious movements are regulated by the cerebrum, the cerebellum influences the less conscious movements of locomotion and plays an important part in the finer muscular adjustments, such as are made by the skilled operators in

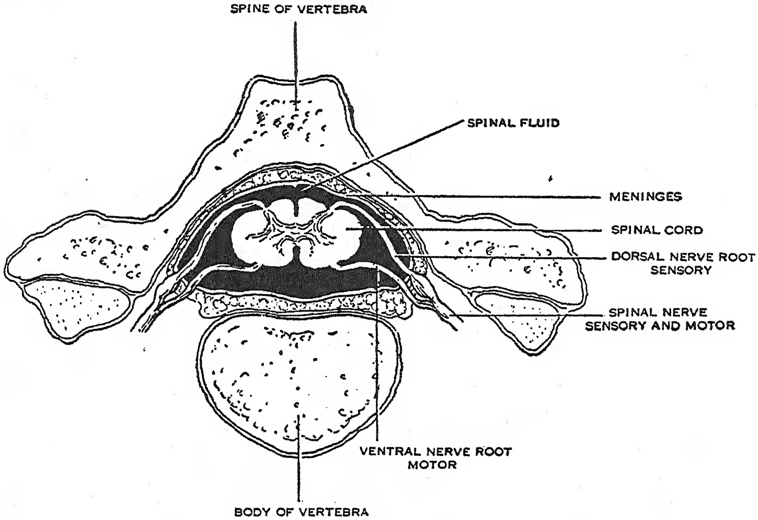

Figure 50. CROSS SECTION OF VERTEBRA AND CORD.
Showing the formation of the spinal nerves from the dorsal and ventral roots.

the arts and trades. These functions are seriously interfered with as a result of injury to the cerebellum.

The Cerebrum.

The short extension of the brain stem above the pons and cerebellum is known as the mid-brain. In it are located centers for motor and sensory nerves from the eyes and ears. The remainder of the brain, and in man by far the largest part, is known as the cerebrum; it fills the cavity of the skull above the level of the eyes. A deep groove runs along the top of the cerebrum from front to back, partially dividing it; the two sides thus formed are known as the cerebral hemispheres.

The surface of the cerebrum is convoluted so that ridges are formed with fissures between them. The locations of the main fissures are constant in all human brains, and in the study of the brain they serve as marks for defining its areas. The surface is covered with a layer of gray matter known as the cerebral cortex. In the center of the cerebral

hemispheres are cavities filled with fluid; these cavities or ventricles are connected with the space between the spinal cord and the membranes which surround it. The fluid in the ventricles and about the cord is known as cerebrospinal fluid.

In addition to the gray matter of the cortex there are large masses in the center of the cerebrum near the ventricles. This central gray matter of the cerebrum controls many important functions and is, as will be seen later, the seat of several diseases. The remainder of the cerebrum is made up largely of the enormous number of fibers which extend between the neurones of the gray matter in the various parts of the brain and spinal cord.

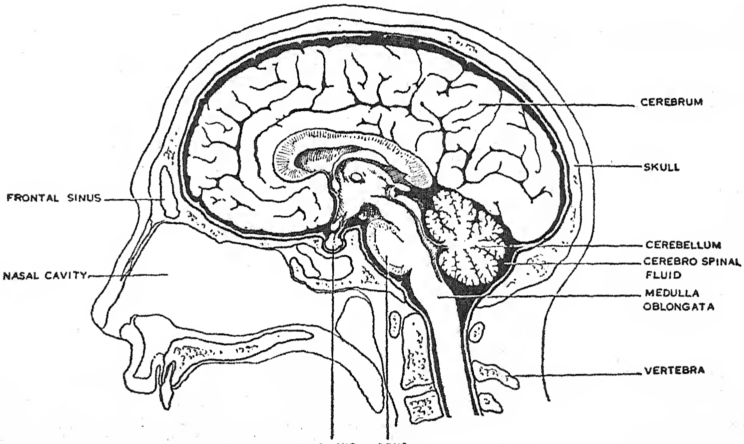

Figure 51. Sagittal Section of the Brain.

The cortex of the cerebrum is the seat of intelligence and reasoning power; in it take place the associations of impressions that constitute thinking, memory, imagination, and the process of willing acts. The particular areas in which the centers for the higher processes are located cannot be accurately defined; they probably include the entire cortex. The regions that control the complex voluntary muscular movements have been definitely located; they cover a vertical strip about midway on each side of the brain. Most of the fibers leading down into the cord from these areas cross to the opposite side, so that the area on one side of the brain controls the muscles on the other side of the body (see Figure 54). For this reason injury to one side of the brain is followed by paralysis of the muscles on the opposite side of the body.

If the cortex of a dog's cerebrum is removed, the animal may still continue to live, to move about, and to avoid obstacles by means of sight, but its intelligence is gone. A man in whom the cortex is extensively damaged by disease cannot reason, remember, or perform any voluntary acts.

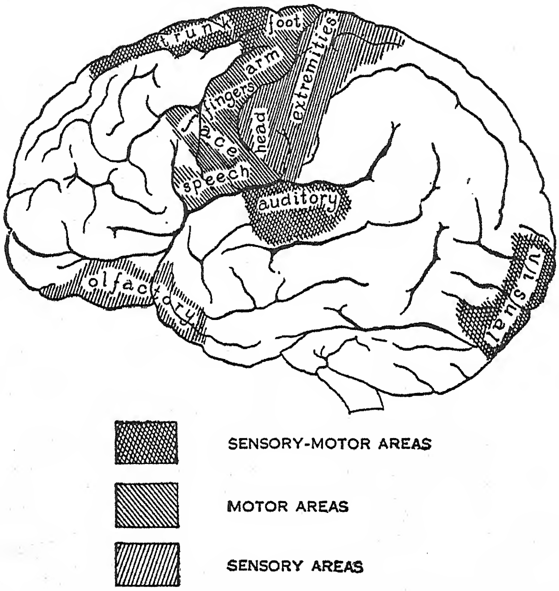

Figure 52. CEREBRUM FROM LEFT SIDE.

The masses of gray matter in the center of the cerebrum control many acts that are essentially instinctive, i.e., complicated unconditioned reflexes and possibly also conditioned reflexes after they have been fully acquired. They also form an important center for the basic emotions that determine temperament.

The Autonomic or Vegetative Nervous System.

The most evident and striking functions of the nervous system are those concerned with receiving and interpreting sensations and with controlling the voluntary muscles. Equally important, however, is the control of the activity of those organs which perform their functions below the level of consciousness, such as the heart, the blood vessels, the pupils of the eyes, the muscles and glands of the alimentary tract, the sweat glands and many other so-called organs of vegetative func-

tion. The nervous control by which these activities are integrated is exercised through what is known as the autonomic nervous system.

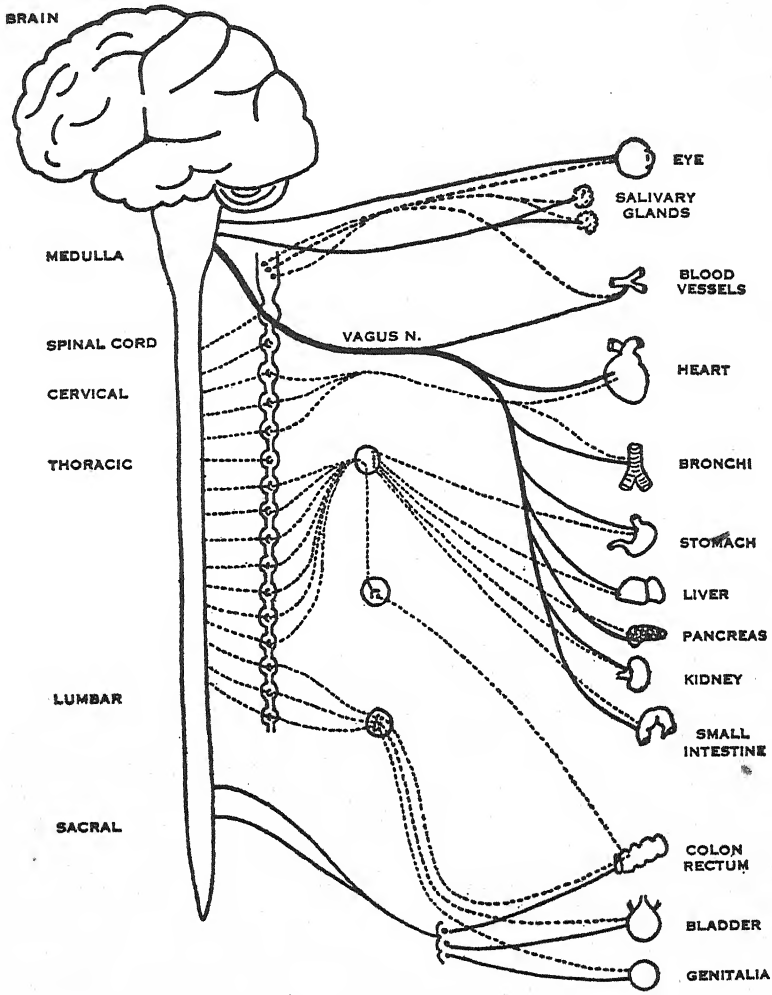

Figure 53. SCHEMA OF THE AUTONOMIC NERVOUS SYSTEM.
Sympathetic fibers shown as dotted lines; parasympathetic, as solid lines.

The autonomic system, on the basis of the effect it produces in the various organs, is divided into two parts: the sympathetic and the parasympathetic. The actions of these two systems are antagonistic,

an antagonism illustrated in the control of the heart rate. The vagus nerve, which belongs to and is indeed the main nerve in the parasympathetic system, acts to slow the heart rate. This retarding influence is antagonized by the accelerating effect exercised through fibers going to the heart from the sympathetic portion of the autonomic system. The balanced action is seen likewise in the movements of the intestines; here the vagus acts to slow intestinal movement, and the sympathetic to hasten it. The pupil of the eye is constricted by impulses from the parasympathetic system and dilated by those from the sympathetic.

The cell bodies of the nerve fibers of the sympathetic system are located in the spinal cord from the level of the first vertebra below the neck (first thoracic) to the second or third below the level of the ribs. Those of the parasympathetic system are in part in the brain, their fibers emerging in the cranial nerves, and in part in the lower portion of the spinal cord.

The fibers of the autonomic system do not run directly from the cord or brain to the organs they control as do the nerves of the voluntary nervous system; instead, they make connections through neurones located outside of the spine. These neurones are collected into groups called ganglia; the main ganglia of the sympathetic system are located on each side of the spine. Others are located among the organs, and of these the one near the stomach called the solar plexus is familiar to boxers as a vulnerable point for a blow.

Some drugs act on the autonomic nervous system, usually affecting only one portion, either the sympathetic or the parasympathetic. Thus belladonna or atropin inhibits the effect of the parasympathetic system. Administration of this drug intensifies the action of the sympathetic portion: the heart beats rapidly and the pupils of the eyes dilate; salivary secretion is stopped, as is also sweating in parts of the body. In testing eyes for glasses the ophthalmologist often applies atropine to the eye to paralyze the parasympathetic nerves, and so dilate the pupil and abolish accommodation.

The dilation of the pupil from fear or other emotion is effected through the action of the sympathetic nerves, as are indeed most of the involuntary effects of emotion, the rapid heart rate, the blanching of the face, the flow of tears, the change in motility of the intestines and the mobilization of sugar from the liver into the blood.

The Meninges and Cerebrospinal Fluid.

Both the cord and the brain are loosely covered with membranes which collectively are known as the meninges. The space between the membrane and the brain or cord is filled with fluid which resembles lymph. This cerebrospinal fluid is continuously produced by filtration from the blood in the ventricles of the brain. It seeps from them outward through narrow passages leading into the space between the meninges and brain or cord. The fluid flows upward to surround the brain, and downward to surround the cord. It is absorbed and carried away in the blood vessels of the meninges. The rate of secretion and absorption of the fluid is so adjusted that the pressure within the skull is normally quite uniform. The amount of fluid ordinarily present is about 130 c.c.

The cerebrospinal fluid serves two main functions: (1) the layer about the brain affords some protection from shocks and vibrations; and (2) the fluid, by rapid absorption, allows a small amount of expansion space for the brain when the blood supply is increased. A hollow needle inserted between the vertebrae low in the back can be passed into the space beneath the meninges without injuring the cord. This procedure is known as spinal puncture. Fluid may then be withdrawn for diagnostic purposes when fractured skull, meningitis, infantile paralysis, or syphilis is suspected. In so-called spinal anesthesia the anesthetic drug dissolved in fluid is injected into the space about the cord; sensations from the lower part of the body are abolished without unconsciousness being produced.

If for any reason the passages leading from the ventricles of the brain to the space beneath the meninges are shut off, as they may be by tumors or by tubercular infection of the brain, the fluid accumulates within the brain and its pressure is raised. Intense pain and disturbance of nervous function may result from the compression of the brain. In infants the skull may be forced out of shape by the pressure and become greatly enlarged, the condition known as hydrocephalus.

Meningitis.

Infection of the meninges, meningitis, may occur from many different organisms, such as the tubercle bacillus, the streptococcus, the pneumococcus, and the meningococcus. Except for the last organism, the infection of the meninges is usually secondary to an infection elsewhere in the body, a complication of tuberculosis of the lungs, a middle ear infection or pneumonia. The meningococcus on the contrary at-

tacks the meninges primarily. This form of meningitis is an infectious disease and may occur in epidemics. Meningococci are frequently found in the throats of healthy people; they act as carriers, spreading the organisms by contact. In susceptible individuals, usually children, the meningococci spread through the lymph channels from the throat to the meninges. Severe illness results, during which red spots may appear on the skin; the pressure of the spinal fluid is increased, and the brain and nerves are irritated so that the legs become stiff and the back is drawn up. Detected early, the disease can often be treated successfully by introducing anti-meningococcus serum into the spinal fluid. The treatment is not beneficial for meningitis caused by other organisms. A drug known as sulphanilamide has been used successfully in the treatment of some cases of meningitis caused by the streptococcus; until this medicament became available, streptococcus meningitis was always fatal.

Pain.

The surface of the body, far more than any other part, is susceptible to pain. There are probably special nerves to carry this disagreeable, but protective, sensation. Light stimulation of them may cause itching and discomfort; strong stimulation, actual pain. The perception of pain is wholly subjective, and hence the intensity of pain is greatly modified by mental factors. In the distraction of extreme excitement, such as anger or religious fervor, injuries that cause severe wounds may not be felt; the anticipation and fear of pain intensify the sensation. Persistent pains are usually felt more severely at night since there is less then to occupy the mind.

When pain arises from the skin there is no difficulty in locating its origin. Pain which arises from the internal organs is not always so readily localized, and may be "referred" to parts distant from the actual seat of disturbance. This referring of pain results from the diffuse distribution of nerves from any one level of the spinal cord. Pain arising from a disturbance of the heart, such as angina pectoris, is frequently felt upon the arm and chest wall. Inability to locate an aching tooth has resulted in the mistaken extraction of sound teeth.

The visceral organs are relatively insensitive; they may be cut, burned, even crushed, without sensation. Severe infection and inflammation may be nearly painless; a sore throat may cause severe pain while pneumonia may cause little or none. Pain from the visceral organs appears to occur mainly from disturbance or exaggeration of

their normal functions. Thus one is totally unaware of the bladder until it becomes distended with fluid; then the demand for evacuation arises and becomes imperative in consciousness; if denied, painfully so. Cramping contraction of the muscles of the alimentary tract is painful, and so also is distention of tubes such as the gall duct, ureter, or intestines.

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Neuritis and Neuralgia.

The term neuritis does not mean solely the inflammation of a nerve; it signifies any inflammation and degeneration of any part of the neurone. In this broad designation it thus includes diseases such as infantile paralysis and locomotor ataxia, discussed elsewhere, in which the primary injury is in the cell body and not in the nerve fiber. Neuritis is not, contrary to common belief, necessarily a painful condition, although it may be so; if the neurones and fibers affected are efferent, the result is not pain but paralysis.

A mild and ordinarily temporary form of inflammation of a nerve results from pressure upon the nerve, as in crossing the legs; the part supplied by the nerve tingles and feels asleep. If the pressure is prolonged, as in sleeping in a chair with the arm thrown over its back and the head resting on the shoulder, the injury to the nerve may be severe and the effects last for weeks. Serious inflammation and sometimes permanent damage of the motor nerves may result from dietary deficiency as in beriberi. It is believed that deficiency of vitamins may be a predisposing factor to neuritis from many causes; certainly it plays an important part in alcoholic neuritis which leads to partial paralysis of the muscles that hold up the feet. Infections such as diphtheria and typhoid fever, and likewise poisoning from such substances as wood alcohol and carbon bisulphide and lead, may be followed by neuritis. Neuritis may also result from exposure to cold; the nerves that supply the muscles of the face are most commonly affected. The chilling may result from riding next to the open window of an automobile, or from applying ice packs too long on the face; the muscles of the exposed side may for a week or a month lose all ability to move. That side of the face is then expressionless, the lower eyelid droops, and the food accumulates in the cheek during mastication.

In the condition called neuralgia there is pain along a nerve, but no demonstrable injury to the nerve. Neuralgia may range in severity from mild annoying twinges of pain to agonizing suffering. One of

the commonest forms of the severe variety occurs in the face along the course of the trigeminal nerve; it is sometimes called tic douloureux. The pain is rapid and stabbing. Cutting the nerve or paralyzing it with injections of alcohol is often the only way in which the attacks of the disease can be controlled.

Paralysis.

Inflammation or other injury to the motor nerves or centers may result in partial or complete loss of motion in the muscles which they supply. When the injury is in a nerve after it has left the spinal cord, only the muscles to which that nerve is distributed are involved. When the damage is in the brain or cord many nerves may be affected, and the paralysis is correspondingly extensive; all the muscles on one side of the body may be involved. Paralysis, especially if originating from the brain, does not signify complete loss of motion. The muscles affected may be rendered tense or made to tremble. The nature of the paralysis is designated by a qualifying term as flaccid (limp) paralysis, spastic (stiff) paralysis, paralysis agitans, etc.

Injury to nerves frequently occurs in wounds. The cutting of a nerve leads to the paralysis or loss of sensation in the area which it supplies. The nerve fibers degenerate. If the ends of the nerve are brought together soon after the injury, new fibers will grow from the cell bodies in the spinal cord or ganglia; these fibers follow the course of the degenerated nerve and replace it. Sensation is then restored and it is possible to use the muscles again. If the ends of the nerves are not brought together, the replacement extends only to the stump of the central end of the nerve and the paralysis is permanent. In a broken back or broken neck the serious effects result from injury to the spinal cord. If the cord is cut or pressed upon by the fractured bone, all nervous connections with the brain are lost below the point of injury. The higher the injury, as in the neck, the more extensive the paralysis and the greater the danger to life from respiratory paralysis. In carrying out first aid when there is possibility of fractured spine great care must be taken not to move the back or neck for doing so may aggravate the injury to the spinal cord.

Infantile Paralysis and Locomotor Ataxia.

Infantile paralysis and locomotor ataxia are infections which damage the spinal cord. In infantile paralysis the injury is in the gray matter in the front part of the cord, that is, the cell bodies of the

motor neurones. For this reason it is called anterior poliomyelitis. The paralysis is motor; the muscles lose the power to move and they undergo atrophy. Locomotor ataxia is posterior poliomyelitis; the

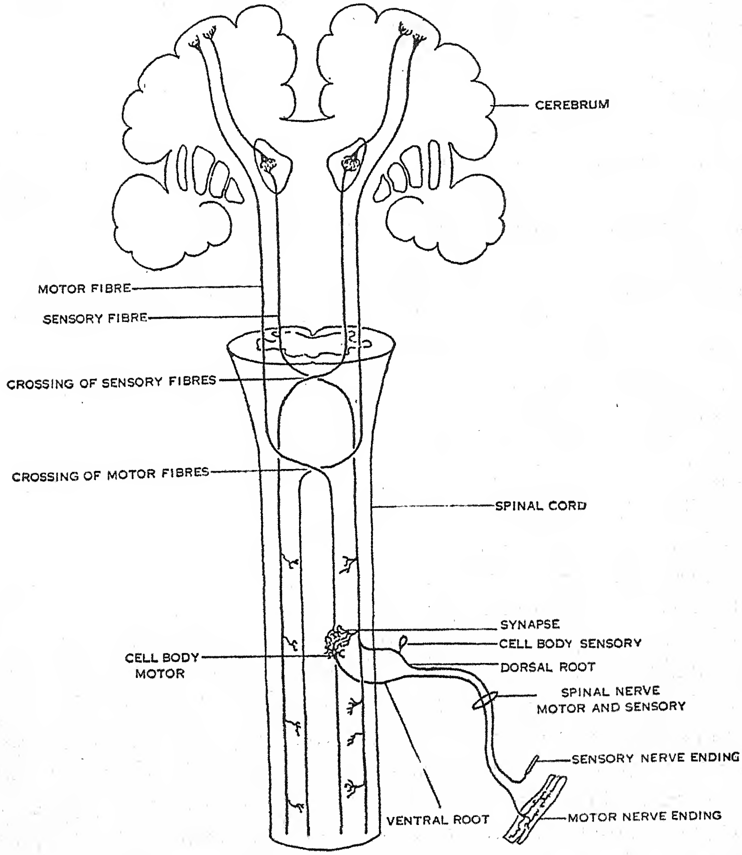


Figure 54. PATHWAYS OF MOTOR AND SENSORY NERVE FIBERS.

damage is in the sensory neurones in the rear of the spine. The paralysis is sensory.

Infantile paralysis is caused by a filterable virus which is spread in the secretions from the nose and throat. In infection the virus is received in the nasal passages and from there enters the nervous system. The disease occurs mainly in the summertime; it may appear both sporadically and in epidemics. It affects children more often than adults. The typical case starts with a feeling of illness, fever and nausea.

In favorable instances the disease may progress no further, all symptoms disappearing in a day or two; there is no paralysis, but the individual affected probably acquires an immunity against subsequent attacks of the disease. Such slight illness is usually unrecognized as infantile paralysis except during epidemics of the disease when many such cases occur. In the more severe form of the disease symptoms of spinal irritation develop a day or two after the initial fever. There is pain in the back and the limbs hurt on movement. Soon the typical paralysis develops. In some cases paralysis is the first indication of the disease; there is no preliminary illness.

The injury from the disease usually occurs in the lower part of the cord; consequently the legs are affected. The infection may, however, extend to any part of the cord; and if high, the muscles of respiration may be paralyzed. It is in such cases that the mechanical respirator is used to support life. After the acute symptoms of infantile paralysis have subsided, careful orthopedic treatment often results in remarkable restoration of function. Spraying the nasal passages with zinc salts or tannic acid to harden the membranes and prevent the penetration of the virus has been used during epidemics as a prophylactic against the disease.

Locomotor ataxia is caused by syphilitic infection. If syphilis is treated early and thoroughly the spinal cord does not become infected; locomotor ataxia occurs only in untreated or poorly treated cases in which the disease has become chronic. The lower part of the spine is affected first; hence sensation is lost in the feet and legs. Walking becomes difficult because of the failure of the sense of position; the individual affected can tell the position of the feet only by looking at them. He walks with a peculiar gait; the legs are thrown wide, raised high and brought down sharply on the heels; in partial darkness he walks with difficulty and he stumbles in climbing stairs. An individual with locomotor ataxia cannot stand upright with the feet together and the eyes closed. A normal person under similar circumstances does not fall, but only sways slightly, maintaining a fairly good balance by means of his sensations of position.

Concussion.

Concussion of the brain as the result of a blow on the head may be followed by immediate unconsciousness. Unless the force is sufficient to cause actual damage to the brain, consciousness returns in a short time. The phenomenon here, except for the fact that the effects

are from the cerebrum, is essentially the same as the temporary paralysis of the ulna nerve, "the crazy bone," following a blow on the elbow. Death may result from severe concussion from paralysis of the respiratory center. The "knock-out" from the blow on the chin in boxing is probably only in part from concussion of the brain; the force also reaches the carotid sinus in the neck (page 148), causing a sudden drop in blood pressure and temporary anēmia of the brain.

A severe blow on the head may rupture blood vessels in the brain. The results are then essentially the same as those from cerebral hemorrhage discussed below. The hemorrhage if large presses on and destroys a part of the brain; the seriousness of the condition depends upon the part of the brain involved and the extent of the hemorrhage. If the hemorrhage is small no permanent ill effects may result. If, as in professional boxing, the blows to the head are repeated over a long time the many small hemorrhages that result lead to permanent damage in the central gray matter of the cerebrum. As a consequence, disturbance in gait, judgment and speech may develop, a condition known among prize fighters as "punch drunk."

Apoplexy.

Apoplexy, so-called, may result either from the bursting of an artery in the brain or from the occlusion of an artery with a thrombus or embolus. Both conditions are common sequelae of arteriosclerosis. If the hemorrhage is large, death occurs within a few days; if it is small, the individual may survive, but usually has some permanent paralysis. The first attack of cerebral thrombosis does not as a rule cause death; subsequent attacks may.

In either hemorrhage or thrombosis paralysis develops, and usually immediate unconsciousness. In favorable cases consciousness is restored in a few hours. As a rule one side of the body remains paralyzed, the side opposite to that in which the hemorrhage or thrombosis has occurred in the brain. If the injury is on the left side of the brain the power of speech may be lost. A few weeks after the "shock," improvement commences, speech may be restored in some measure and the paralysis gradually decreases.

Sleeping Sickness.

A type of sleeping sickness occurs in Africa as the result of infection by an animal parasite carried by the tsetse fly. This disease has no relation to the so-called sleeping sickness, encephalitis lethargica, which

occurs in temperate regions. This disease came into prominence following the World War when it first occurred in recognized epidemics. Since then the disease has occurred sporadically and in many small outbreaks. Presumably it is caused by a filterable virus, but the agent and its mode of transmission have not been determined.

The infection causes an inflammation of the brain, particularly in the region of the central gray matter of the cerebrum. During epidemics the disease frequently starts with illness and fever during which there is extreme drowsiness. Death may result, but more frequently the acute symptoms subside and the disease passes into a chronic state. The sporadic cases usually do not show the acute symptoms, those of the chronic stage being the first that are recognizable. The chronic effects of encephalitis lethargica may show as tremors or muscular stiffness; the play of the muscles of expression may cease so that the face becomes mask-like, expressionless, and the emotions may become unstable, particularly in children.

In addition to the common type of encephalitis lethargica there are exceptional forms which so far have been limited largely to Japan and to St. Louis, Mo. The initial illness is usually severe, resulting in death in 20 per cent of the cases occurring in the United States, and a much higher percentage in Japan. In those who recover there are rarely any of the serious chronic effects which occur after the ordinary type of the disease.

Tremors, Tics and Convulsions.

Disturbances of the central nervous system are not manifest at the point directly affected; instead, there is some alteration in the action of organs with which the nerves from the affected area of the cord or brain are connected. Thus a blood clot pressing upon the brain results in paralysis of one side of the body; but no headache or other symptoms occur in the area of the real damage. Often disturbance in the nervous system results in overaction of muscles, which is designated according to its intensity and nature as tremor, spasm, or convulsion.

Tremor is a rapid to-and-fro movement of antagonistic muscles. In an otherwise normal individual it may be occasioned by fatigue, or by the toxic action of coffee, tobacco or alcohol. In chronic alcoholics the tremor may become permanent.

The so-called "shaking palsy," or paralysis agitans, seen most commonly in elderly people, results from changes in the masses of gray matter at the base of the cerebrum. The disturbance may be caused

by arteriosclerosis in the brain; it is also a common sequel to encephalitis lethargica. The tremor in the hands gives rise to a peculiar and characteristic movement; the thumb and index fingers are rubbed together as if some object were being rolled between them.

A convulsion is an involuntary and purposeless, that is, incoordinated muscular contraction. When limited to a small group of muscles it is spoken of as a spasm. The rapid twitching of the eyelid, which many persons experience as the result of fatigue or eye strain, is a spasm. Hiccoughing is due to a spasm of the diaphragm.

A type of muscular movement known as "tic" resembles a spasm, but is distinct from it in that the tic is not caused by an irritation or derangement of the nerves. A tic is a habit spasm—a movement occasioned at first by some local cause such as rubbing a sore spot on the face, or by the imitation of someone else, and repeated until it has become habitual. The movements involved in the tic are those of any voluntary act, but the motions are usually exaggerated, such as repeated winking, drawing up the eyebrow or cheek of one side of the face into a grimace, licking the lips, nodding, sniffling, coughing, scratching or tapping some part of the body.

Convulsions involving large groups of muscles sometimes occur in children; they may be due to digestive disturbances, the beginning of an infection, or to irritation of some organ such as the bladder. Usually they pass off and have no after-effects; they are merely an expression of the lack of stability of the immature nervous system. If the convulsions occur repeatedly, they are possibly due to epilepsy.

Epilepsy.

Epilepsy arises from a disturbance in the cerebrum. It is characterized by sudden loss of consciousness, with or without convulsive movements of the muscles. The attacks take the form of what is known as either *petit mal* or *grand mal*. In *petit mal* there is loss of consciousness for only a few seconds; there are no convulsions beyond blinking and rolling the eyes or some apparently purposeless movement of the hands. The individual does not fall down. Attacks may occur frequently but do not interfere with the activities of the individual. They do, however, make him a hazard in traffic, both as a pedestrian and as the driver of a car, and in many factory occupations. The seriousness of *petit mal* lies in the fact that it may later pass into *grand mal*.

The *grand mal* of epilepsy is the seizure that most people have in mind as epilepsy. The severity of the convulsions varies greatly; in

mild attacks there is only momentary rigidity and twisting of the body, with perhaps some drooling of saliva. In a severe attack all the muscles contract rigidly; air is forced from the chest with a grunting sound; the jaws are clenched and if the tongue is between the teeth it is severely bitten; the face may turn bluish. This rigidity of the body lasts from a few seconds to nearly a minute. It is followed by violent muscular movements which jerk the body and limbs. Air is sucked into the lungs and frothy saliva is blown from the mouth. The violent jerking lasts from one to several minutes; it then lessens and finally ceases. The individual is left exhausted and sleepy; his muscles are sore. It may be several days before he recovers fully from the ill effects of the attack. Some epileptics shortly before an attack have sensations of dizziness and weakness; these symptoms, called an aura, may give a warning that allows the victim of the disease to sit or lie down and so avoid falling.

Attacks of epilepsy may occur at any time in those afflicted, even during sleep; they often occur in public places. In such circumstances the bystander can afford only slight assistance; he can prevent the epileptic from injuring himself during the convulsive movements and prevent him from biting his tongue by inserting a piece of wood or a rolled handkerchief between his teeth. Other first-aid treatment is useless. After the fit is over, the man should be removed to a quiet place where, after he recovers, he may be spared the embarrassment caused by those whose curiosity leads them to stop and watch the epileptic have his fit.

The cause of epilepsy is not known. In the families of most, but by no means all, of those affected, there is an unusually high occurrence of epilepsy or mental diseases. Epilepsy usually makes its appearance early in life, the two main periods being during the first and second years and at puberty. Many treatments have been used for epilepsy; and while some, such as a diet high in fats, succeed with occasional cases, none succeeds with all.

In one form of epilepsy, called Jacksonian epilepsy, the convulsions may be due to pressure on the brain either from a fragment of bone displaced by injury to the skull or from a growth such as a tumor or cyst within the brain. Jacksonian epilepsy can sometimes be cured by surgical operation; but for success the operation must be performed soon after the first appearance of the attacks. The ordinary types of epilepsy are not benefited by operation.

Headache.

Headache is a common ailment, but the physiology of the disturbance is far from clear. The pain is usually from within the skull, but the exciting cause in most cases is in some other part of the body. The gray matter of the cerebrum and, in fact, most of the brain, except in the regions about the central cavities, is insensitive to pain. One of the layers of the meninges, and especially the area about its blood vessels, is sensitive. Increase or decrease in the pressure of the cerebrospinal fluid may affect these parts and cause headache. The headache that follows carbon monoxide poisoning, and possibly also that from alcoholic intoxication, is caused by pressure; the brain absorbs fluid and swells. Likewise the pressure from brain tumors causes headache. In many instances changes in the circulation that may be associated with such mild disturbances as constipation alter the pressure within the skull and cause headache. Many headaches are due to referred pain from infection of the sinuses and especially from eye strain. A typical instance of referred pain to the head, in this case to the front part and only momentarily, occurs in some people when they swallow ice cream too hastily.

Most headaches are merely unpleasant symptoms of disturbance in some part of the body other than the brain, but there is one type of headache that stands alone as a primary condition. It is known as migraine, or "sick headache." In this condition the pain usually starts in one side of the head, but may spread to the other. It is often associated with nausea and vomiting. There may also be disturbances of vision, such as bright lights shooting before the eyes, or blind areas surrounded with glistening rims. There may also be bewilderment. If severe, these attacks are incapacitating. The disease tends to run in families. In some cases the cause is believed to be due to an allergy similar to that which leads to hay fever or asthma. In other cases it appears to be associated with disturbances in the glands of internal secretion, especially those of the ovaries and testes; the attacks in women often occur near the time of menstruation and they may cease during pregnancy and after menopause. In still other cases of migraine the cause is unknown.

Sleep.

Many theories have been advanced, but no certain explanation has yet been found for the cause of sleep, or, indeed, for the obvious need for sleep. Prominent among the suggested explanations are diminution

in the blood supply to the brain, the formation of hypnotic chemical substances in fatigued tissues, a lessening of the stimuli received by the brain from the muscles, a psychological inhibition in the cerebrum similar to that occurring in the motor reflexes for the exclusion of interfering activity in reciprocal motions, and finally the activity of a definite center for the control of sleep located in the gray matter at the base of the cerebrum. There is much evidence, particularly from the study of diseases, that even if there is no actual sleep center, the region about the ventricles of the brain plays an important part in sleep; this is the region which is injured in encephalitis and other diseases which lead to excessive sleepiness.

The outer layer of the cerebrum, the cortex, is not essential to the production of sleep; it does, however, play a part in the sleep rhythm, that is, bringing all sleep into one daily period. This rhythm is a conditioned reflex, an acquired habit. An animal with the cortex of its brain removed, and also young animals and human infants, do not have this rhythm; they have several sleeping periods throughout the day. The cortex is able within limits to counteract the activity of the sleep center. The more stimuli received by the cerebrum, the more readily it can do so. Thus a strong stimulation from noise or touch or pain prevents sleep and will cause awakening from sleep. Contrariwise, the lessening of stimuli as in darkening the room and excluding noise is conducive to sleep, as is also monotony. Drugs, such as caffeine, which excite the cerebral cortex, cause wakefulness, and those which depress it hasten sleep. Many of the sleep-producing "medicines," however, have their main action, not on the cortex, but upon the gray matter at the base of the cerebrum—the region of the presumed sleep center.

No demonstrable changes in the body of healthy adults follow prolonged loss of sleep, i.e., up to 100 hours of wakefulness. Irritability, nervousness and difficulty in performing coordinate movements may develop, but no illness. The irritability and excitement from lack of sleep may of themselves prevent sleep even when it is sought. The fact that healthy adults can survive loss of sleep without serious harm does not signify that those who are young or ill can do so. Likewise it does not exclude the possibility of ill effects from repeated loss of sleep.

There is no set figure for the amount of sleep needed by different individuals. There appears to be for each one a minimum below which the effects of lack of sleep become evident, but this minimum is widely variable. Some individuals, particularly those of excitable temperament,

appear to need less sleep and to obtain it with more difficulty than those of phlegmatic temperament.

The first two or three hours of a night's sleep are usually deeper than the remaining five or six, but there is no evidence to show that they are any more restful. The recuperating value of sleep appears to depend upon its length rather than its intensity. For most healthy adults six hours of sleep gives the needed recuperation; the customary eight hours allows an ample margin of safety. Children, however, need more; an infant may sleep eighteen to twenty hours a day, and a growing child twelve. Old people usually sleep for a shorter period at night than young adults, but tend to nap during the day. A period of excessive sleep is frequently followed by drowsiness and depression; and lack of sleep by a temporary period of excitement, followed some hours or even a day later by depression.

Insomnia, the inability to fall asleep, only occasionally troubles the young, but is a distressing disturbance for many adults. It is particularly prone to occur in those of excitable temperaments, rarely in the phlegmatic. Excitement, anxiety, worry and failure to relax the muscles are contributing causes. Most chronic insomnia, however, like the onset of sleep itself, appears to be a conditioned reflex—the habit of insomnia—often exaggerated by the fear of not being able to fall asleep. Insomnia may sometimes be remedied by developing a "ritual" of sleep, i.e., repeating a series of acts in preparation for sleep until the sleep itself becomes a part of the habit. Such a ritual may consist of regular hours for going to bed, a warm bath and a warm drink before retiring, muscular relaxation in bed and a train of thought on some unexciting subject repeated each night.

Somnambulism, or sleepwalking, occurs more commonly at the age of puberty than at any other period. If frequent, the aid of a psychiatrist should be sought, for somnambulism may result from some nervous or mental disturbance. The sleepwalker has his eyes open but fails to observe other persons; the direction of his walk is frequently determined by beams of light as from the moon. Obstacles are avoided but, contrary to popular belief, accidents and injuries frequently occur. Again contrary to such belief, no harm results from waking the sleepwalker.

Somniloquy or sleeptalking is usually concerned with dreams and may extend to the point where an individual sits up in bed and illustrates his dreams with gestures. Occasionally sleeptalkers will respond

to questions. Some individuals, especially children, sleep with their eyes open instead of closed; the eyeballs are rolled upward.

Personality.

Among animals, low in the evolutionary scale as compared to man, which have little or no cerebral cortex, the behavior of each individual is virtually identical with that of all others of its kind. Thus each bee or ant behaves in a definite and precisely predictable manner. Any difference in behavior as between drone or queen or worker bee is determined, not by training or education, but by definite anatomical differences in the nervous system. Such animals may show highly complex behavior, but they were born with a knowledge of this behavior. Their actions are controlled by instincts; and instincts in turn are essentially elaborately developed unconditioned reflexes, established by the set anatomical structure of the nervous system. Such animals have virtually no individuality, hence no personality; they have group personalities or natures.

In animals higher in the evolutionary scale, and hence with greater development of the cerebral cortex, group nature persists, but wide individual differences appear. Thus dogs and cats as two species of animals behave differently; there is a canine and a feline nature; the differences are due to differences in the structure of the nervous systems of the two animals. But one cat may behave differently from another cat, and one dog from another dog. Each possesses individuality or personality. These differences can be accentuated by training and education. Therefore the environment has its permanent influence in shaping the character of the individual's behavior. But as profound as this influence may be, there are also limitations to its extent; these limitations are imposed by the inborn and ineradicable characteristics of the animal.

Individuality is shown in the highest degree by human beings. There is a common human nature which all men possess; it distinguishes and characterizes the behavior of human beings as definitely as do the peculiarities of the human physical build. Such fundamental human nature cannot be altered in the race except by the process of evolution. But within the limitations imposed by this common nature there are wide differences, both inborn and acquired. Each man has certain individual peculiarities in such qualities as temperament and intelligence which are determined by his heredity. They are as distinctive of him as the color of his eyes or his physical build. Such inborn qualities

impose limitations upon the development of character from environmental influences. The shaping of character is effected through the operation of the psychological mechanisms, with which the study of psychology is largely concerned. This shaping of character is the most essential part of the development of the individual since it involves all influences from environment, including education; it is, however, beyond the scope of this book. On the other hand, the inborn qualities, such as temperament and intelligence, founded as they are in the anatomical structure of the human nervous system, are as much a part of physiology as is the circulation of the blood.

Temperament appears to be centered largely in the older portion, evolutionarily speaking, of the cerebrum and hence in the region of the central gray masses. Intelligence is unquestionably dependent upon the structure of the most recent and, in man, most highly developed portion of the cerebrum, the cortex. The general temperamental level of the individual is established by the structure of his cerebrum, and he is consequently basically irritable, gloomy, cheerful, or anxious. The cortex through intelligence may, under training and education, exercise a controlling influence upon temperament or at least upon its manifestations. Thus an irritable individual or an anxious one may learn to control the manifestation of his temperamental peculiarities. The first essential to such control is self-understanding. The qualities must be recognized before the control can be exercised.

Intelligence and Feeble-mindedness.

Although some scientists may question the positive statement that temperamental qualities are wholly inborn, none questions the fact that the individual quality of intelligence may be inborn and hereditary. It is, moreover, one of the qualities of personality which by psychological test permits a reasonable degree of comparative evaluation.

Intelligence is the capacity for constructive thinking, for reasoning accurately from premises—that is, for the brain on receiving certain sense impressions to work out a suitable reaction to a new situation of some degree of complexity. It is the ability to arrange the separate impressions gained from information and experience into a concrete product; the ability to build new responses with the material of thought which the nervous system supplies, in contrast to mere learning by rote, parrot-like reproduction of rather simple acquired reflexes. The facility with which this process is carried out and the accuracy and

complexity of the product depend upon the degree of intelligence. Not all adults are equally intelligent.

The degree or level of intelligence attained by an individual, barring malformation of the brain and disease, depends largely upon inheritance; intelligence cannot be acquired. Every human being is born with a capacity which will develop to display some particular degree of intelligence, but no more. There is a progressive increase in the display of intelligence from that at birth to some upper limit beyond which the capacity ceases to increase.

Intelligence should not be confused with knowledge. Some degree of intelligence is necessary to the acquisition of knowledge. Thus a normal child of thirteen years can acquire more complex information and in greater amount than a child of six or eight. The amount of knowledge may be out of all proportions to the intelligence. A man of relatively low intelligence may be a veritable encyclopedia of information; and yet, through the non-productiveness of his intelligence, he may be unable to apply this information to new ends. Knowledge is not intelligence; it is the raw material upon which intelligence draws to synthesize its product. A man who has knowledge, but who is handicapped with a low degree of intelligence, may give a false impression of intelligence and capability. Yet he is incapable of success in a position requiring any considerable degree of intelligence. A man of relatively high intelligence, but with a lesser amount of knowledge, may at first be underrated; but he is soon found to be capable of acquiring knowledge and, furthermore, of applying it.

Feeble-mindedness.

An individual is said to be feeble-minded or mentally deficient when, by the age of adolescence, he fails to show more intelligence than that of a normal child twelve years of age (an I.Q. below 70). Those who fail to attain more intelligence than is shown by a child of two or three years (I.Q. less than 20) are classed as idiots; those whose range is from three through seven years (I.Q. 20 to 50) are imbeciles; and those with a range from eight to twelve (I.Q. 50 to 70) are morons. Idiots are incapable of any occupation; imbeciles of the higher grade may do simple tasks, such as weeding a garden under supervision. The lower grade of morons are able to perform such tasks as scrubbing or mending; middle-grade morons make good workers at manual routine under supervision, and high-grade morons are capable of operating machinery or doing routine work without close supervision.

Characteristics of the Feeble-minded.

Although a man of forty years may show an intelligence which would be normal for a child of ten, it does not necessarily follow that the adult is directly comparable to the child. A normal child of ten can learn to do a great many things; there are also many things that he can learn but cannot accomplish because he is not physically able. This incapacity is not present in the feeble-minded adult, for he is physically mature. Therefore, the feeble-minded adult has a larger range of capability than the normal child. Also the adult has had a longer and wider experience than the child, and has therefore learned empirically how to proceed in many situations which he could not reason out when he first encountered them. Thus in some aspects the feeble-minded adult gives, superficially at least, the impression of having a higher intelligence than that of a child of equal mental age. The normal child is not expected to set himself at work voluntarily, to keep himself at work, to show responsibility, or to use good judgment in meeting the emergencies which arise in connection with his work. These qualities are frequently expected in the feeble-minded adult because of his age and physical development. In fact, however, in these qualities he has no advantage over the boy of equal mental age, and he should be treated accordingly.

There are no sharp demarcations of characteristics which serve to differentiate a feeble-minded from a normal-minded adult. The division is made at the minimum degree of intelligence which allows a man to function successfully in his environment. A man is thus normal-minded if he is sufficiently intelligent to earn his living and manage his own affairs; a man is feeble-minded if he has not enough intelligence to compete on equal terms with men of this normal level. The distinction between normal- and feeble-mindedness thus turns upon the complexity of the environment in which the man functions. An intelligence which is sufficient to allow a man to earn his living and manage his affairs in a passable manner in a small rural community may be insufficient for the same man when he attempts to live in a city. Thus by merely changing his environment he passes from being relatively normal-minded to being feeble-minded.

The idiots and imbeciles are of such low mentality as to be incapable of functioning independently in any civilized community. Morons are capable of functioning in a simple environment. When the environment becomes even slightly complex, those of this class may cease to behave normally; their abnormalities often take the form of pauperism,

crime or prostitution. The great majority of criminals, paupers and prostitutes who are detected and who are therefore in institutions are persons of feeble mind from environments which were too complex for their mentalities.

It was at one time believed that feeble-mindedness was largely a matter of heredity, and that eugenics and the sterilization of the feeble-minded afforded the only solution to the problem. It is now recognized that only a third or less of all mental deficiency is due to heredity. The hereditary or familial types are limited almost wholly to the moron groups. The remaining 70 per cent or more of mental deficiency, including all the idiots and imbeciles, is due to injury or disease of the brain or to disturbances of the glands of internal secretion. Sterilization and eugenics unfortunately are not, therefore, panaceas for mental deficiency (see page 533).

The Psychopathic and the Psychoneurotic.

An individual is said to be psychopathic when the components of his personality are out of balance, when one or more components show such deviation from the normal or average as to give him strongly distinguishing peculiarities. The term psychopathic is not necessarily a stigma, for some of the most successful and famous men have been highly psychopathic. The peculiarities of their personalities which have distinguished them from more normal or average men have been the source of their genius. Thus, although the term psychopathic is not as a rule applied in this way, the fact remains that a man of exceptional intelligence is psychopathic unless all the other qualities of his personality are likewise superlative, an exceptional occurrence. Contrariwise, a man of low intelligence, such as a moron, is not classed as psychopathic because of this deficiency alone; indeed, he may be, and often is, a well-balanced individual since his other qualities correspond to his low intelligence.

Symmetry of personality is, figuratively, comparable to symmetry of body. Symmetry is desirable; but the fact remains that those with the best-proportioned and most graceful physiques are not always the most useful and productive individuals. Few people have physical builds which are perfect; likewise few so-called normal individuals have perfectly balanced personalities. Some "normal" men are more cheerful or more irritable or more moody than others. In spite of these variations they adjust well to their environments. There are, however, men who show peculiarities of personality to such an extent, who are

so extremely psychopathic, that they cannot adjust to any ordinary environment. Between this extreme and the most normal individual there are all degrees and gradations. The psychopathic personality is not therefore a definite condition marked off sharply from some normal state; it is not a disease. The question is not who is or who is not psychopathic, but to what degree each individual is psychopathic. It must be remembered also that the term psychopathic takes for its standard of comparison the behavior of individuals in an environment to which most—that is, the average—men adjust well. Under unusual environments, as in war, the psychopathic individual who adjusts to average conditions with difficulty may find a situation that precisely suits his peculiarities, so that from failure in the common run of life he rises to great eminence in the unusual.

When personality is markedly deviated in one of its basic elements it is difficult for the individual to react to his environment in a healthy, straightforward manner or to accept his normal responsibilities. The deviation may be in one or more elements or in one or more parts of a single element. It is therefore impossible to make sweeping classifications; instead, each individual can be classified only according to his predominant peculiarity in temperament or ego or impulse. Thus he may be abnormally irritable, explosive, gloomy, moody or anxious; he may be weak in ego or egocentric; and he may be weak or strong in impulse.

With self-understanding and good training for character formation, even the markedly psychopathic individual may adapt himself reasonably well to the average environment; without such special aid he may be wholly unable to do so. In consequence he may develop, through the operation of the psychological mechanism, what is called a psychoneurosis. He may show the physical symptoms of disease when there is no anatomical basis for disease. Thus his heart may palpitate or he may suffer from severe indigestion. Although sometimes dismissed as "imaginary ailments," these disturbances seem real to the sufferer. These physical expressions of an inability to adjust to an environment may constitute a form of evasion or escape, or they may be the expression of an abnormal anxiety. Some psychoneurotic individuals feel continually fatigued without apparent cause; others develop obsessions that force them to perform seemingly senseless acts; and still others acquire phobias which give them unreasonable fears. In a type of psychopathic disturbance known as the hysterical personality the physical symptoms may be extreme, such as total blindness,

deafness, or paralysis. In such individuals miraculous cures are sometimes effected by faith healing. Unless, as is the aim in the branch of medicine known as mental hygiene, the environmental obstacles to adjustments are removed as well as faith in recovery inspired, the physical symptoms usually return, but in some other form.

Mental Illness.

A psychopathic or psychoneurotic individual is not, in the accepted sense of the word, insane. Insanity is a state largely defined by legal rather than physiological or psychological criteria, in which the individual is adjudged irrational. The responses made by normal men may vary widely under similar stimuli, but all fall within a range of variations constituting rational behavior. When the function of the cerebrum is disordered, a man may make irrational responses to stimuli or even respond to stimuli which arise wholly from the disordered condition of the brain. His conduct is then judged irrational; such a man is said to be mentally ill.

Mental illness and feeble-mindedness are quite different. The intelligence of a man who is mentally ill may deteriorate until he becomes feeble-minded. The feeble-minded man, on the other hand, has failed to develop intelligence; he has not deteriorated. The distinction is the same as that between two men dwarfed in stature, one because he failed to grow and the other because he has had his legs cut off.

The major mental illnesses, called psychoses, can, for simple classification, be divided into five groups:

1. *Symptomatic Psychoses.*—These are mental disorders which occur during the course of and are symptoms of infections and other physical diseases. Included in this group are the delirium of fever and exhaustion and the mental symptoms which may accompany such diseases as pernicious anemia or exophthalmic goiter.

2. *Psychoses Due to Organic Brain Diseases.*—These are mental disorders which result from actual anatomical changes in the brain, such as paresis from syphilis of the brain. Included in this group are mental disturbances which may result from arteriosclerosis of the cerebral arteries, senile degeneration of the brain, brain tumors and encephalitis.

3. *Psychoses Due to Poisons.*—The most important of these psychoses are those due to alcohol, such as delirium tremens and acute hallucinosis. Lead poisoning may result in psychoses, as may also the use of morphine and other drugs.

4. *Affective Psychoses.*—These are mental disorders of which the cause is not known; the symptoms are usually from disturbances in mood (hence the term affective); and there is often recovery, but also a tendency to recurrence. The important psychoses of this group are manic-depressive insanity and reactive depressions.

5. *Schizophrenic Psychoses.*—As in the previous group, the cause of these psychoses is not known. The disturbance may involve the whole personality and lead to severe maladjustment to the environment, with delusions, hallucinations and bizarre conduct. The condition is usually permanent.

Paresis.

Only a small portion of all cases of syphilis—and those only the untreated ones—lead to paresis; but syphilis is still so extremely common that many cases of paresis develop. The psychosis may appear many years after the original infection. For some time before the actual psychosis becomes clearly evident there are changes in personality and the individual alters his mode of life; there may also be physical symptoms such as dizziness and headache. The psychosis itself often takes what is known as a grandiose form. The individual affected feels unusually happy; he believes his capacities and his wealth are unlimited; that he can accomplish anything; he believes that he is the President of the country, that he is inspired by God and that he owns all the battleships in the world. Gradually as the disease progresses the individual's mind deteriorates; he becomes weak and finally bedridden. The progress of paresis can often be stopped and considerable improvement obtained by treatment which rids the body of the syphilitic infection. In this stage of syphilis the medicaments ordinarily employed are not effective; but elevating the body temperature, either by heat or by malarial infection, may kill the parasites.

Manic-depressive Psychosis.

In this psychosis there may be intense excitement with almost ceaseless activity, the manic phase of the disease, or depression to the depths of despair, from which it is difficult to arouse the individual and in which, unlike the manic phase, he moves little. Usually the attacks are not continuous but occur at intervals. Some individuals show in succession first the manic and then the depressive phase of the disease; others show only the manic or the depressive. There is usually little mental deterioration with the disease, and between attacks the

individual may appear normal. In one form of this psychosis, known as the reactive type, the depressions follow disappointments, sorrows, and other disturbances. Normal men are depressed by disappointment and sorrow, but the man with the reactive type of manic-depressive disease responds in an abnormal degree.

Schizophrenia, or Dementia Praecox.

Dementia praecox, as the name implies, is a disturbance of the young; the majority of cases appear before the twenty-fifth year. There are several forms of the disease, but all have in common a gradual mental deterioration leading in many instances to dementia. In the most common form of dementia praecox the young man (or woman) loses the accustomed activity and energy, and becomes self-absorbed, shy, sullen and seclusive, or perhaps irritable and obstinate. He is moody and indifferent to responsibilities. He may refuse employment and sit for long periods in self-absorption, or he may become restless and wander from place to place like a tramp, begging and committing small thefts. In some cases the disease progresses no further; in other cases the man becomes childish, acts foolishly, and laughs in a silly manner without provocation. In one manifestation of dementia praecox, the so-called catatonic form, there are stages when the individual may become stuporous and must be fed by a stomach tube, or he may display a stereotyped movement and for days repeat some purposeless act, or remain motionless in any position in which he is placed. In still another form of dementia praecox, the paranoid, the mental deterioration is accompanied by fantastic delusions and even hallucinations of persecution. Here the person believes the neighbors are conspiring against him, and that by means of wireless telegraphy they send derogatory messages into his room. The most insignificant occurrence, such as two people talking together, forms a basis for the persecution which he believes he is undergoing.

Nervous Breakdown.

The term "nervous breakdown" has no definite diagnostic significance in medicine. It is used as a "polite" designation to cover the incapacity resulting from any one of a great number of disturbances which are psychological in origin. Thus one of the recurring attacks of depression in an individual who suffers mildly from manic-depressive psychosis might be explained as a nervous breakdown, as also might

an anxiety attack or any psychoneurotic disturbance precipitated by frustration. Hard mental work, if successfully completed, does not result in "nervous breakdowns"; but if failure instead of success results from the work, the "breakdown" may, in a psychologically susceptible individual, follow from the frustration.

CHAPTER XV

THE EYE AND EAR AND THEIR DEFECTS

IT IS THROUGH THE VARIOUS SENSES THAT WE OBTAIN KNOWLEDGE OF OUR surroundings. The sense of touch gives information concerning objects with which the body comes into actual contact. The sense of taste distinguishes certain properties of soluble substances placed in the mouth. The sense of hearing affords information of the vibrations in the surrounding air which we call sound. Hearing, unlike touch and taste, gives information of events occurring at a distance from the body. The sense of sight reaches still farther into space; there is perception of light even from a star at a distance of a thousand "light" years. In many animals smell also is a sense which is important in affording information regarding food and enemies at a distance.

The Skin as a Sense Organ.

The skin, when suitably excited, gives rise to the sensations of touch, warmth, cold and pain. The skin itself is not a receptive organ for these sensations; but it is dotted with sensory nerve endings, some of which respond to touch, others to cold, others to heat, and still others to insults causing pain. Except in the case of those for pain, the nerve fibers are adapted at their terminals in the skin with minute receptor structures specialized to convert the appropriate stimuli into a nerve impulse.

There are on the body some 250,000 minute spots which are receptive to the sensation of cold. Each "cold spot" is connected to its individual nerve fiber going to the spinal cord or brain. There are some 30,000 spots which respond to heat. The skin between these points is insensitive to cold or heat, although if either is applied it is soon felt because of heat conduction through the skin to or from the nearest sensitive spot.

The terms heat and cold, as they are used here to express opposite conditions, necessitate the assumption of some normal temperature; above this normal is "hot," and the heat spots react and give rise to the sensation of warmth, while the cold spots are not excited. Tempera-

tures below this normal are what we term "cold"; the cold spots are excited, while the hot spots are not. This normal varies with many conditions, so that the sense of temperature is subject to numerous deceptions. Thus the sensation of warmth is caused by immersing the hands in cold water after they have been chilled by exposure to extreme cold, while tepid water feels cold after hot.

The sensations of heat and cold are excited in proportion to the rapidity of change in temperature. We can sit comfortably in a room while the temperature is slowly decreased 5° F. during the period of an hour. On the other hand, on stepping from one room to another 5° cooler or warmer, the difference in temperature is at once appreciated.

The intensity of the sensation of temperature depends upon the size of the skin area exposed and consequently on the number of receptive organs stimulated. If the whole hand is dipped in water at 98° F. it feels warmer than water at 105° into which only one finger is dipped. This fact is of practical importance in bathing infants; the temperature of the bath water in which the whole body of the infant is to be immersed should not be tested with the finger or hand but should be determined with a thermometer.

It has been estimated that there are more than half a million points on the skin which respond to stimulation by producing the sensations of touch and pressure. A person pricked on the skin with the point of a needle can tell with the eyes closed exactly where the needle is applied. This localization results from the fact that each one of the touch and pressure points is connected to the central nervous system by its own nerve fiber. Hence each elicits a different sensation which is mentally projected to the area of skin excited. If the skin is pricked in two spots very close together, it may be difficult or impossible to differentiate the two points, and they are felt as one. The distance that the points must be separated to be felt as two depends primarily upon how thickly the touch and pressure points are scattered over the area examined, upon other facts such as practice, and upon whether the application of the two needles is simultaneous or in succession. An instructive experiment can be performed in this connection by gently pricking the skin with a draftsman's pen and widening the points until two spots are distinguished. In the average individual the tip of the finger will distinguish two points at a separation of about 2 mm., the back of the hand 20 mm., the chest 45 mm. and the middle of the back 60 to 70 mm. The distance is the least where the skin is used for the most delicate touch and where the discernment of slight intervals between objects is most necessary.

Disturbance in Cutaneous Sensation.

Sensation in the skin is influenced, not only by diseases of the skin, but also by disorders of the nervous system. When the perception of pain is lost the area so affected is said to be anesthetic. When a nerve trunk is severed in a wound the area of the skin supplied by the nerve becomes insensitive. The skin in the anesthetic area may be struck or burned without giving rise to any sensation. Some drugs, such as cocaine and novocaine, interrupt the transmission of nerve impulses. When injected beneath the skin or about a nerve they produce a temporary local loss of sensation. Surgical operations may be performed under this local anesthesia.

In contrast to anesthesia, the skin may be more than normally sensitive, a condition known as hyperesthesia. When the skin is inflamed, as in sunburn, it is painfully sensitive to touch. When the superficial layers of the epithelium are lost through the bursting of a blister or by abrasion, the area thus denuded is sensitive, for the nerve ends have lost the protection of the epithelium. Hyperesthesia may be of the nature of a referred pain. Thus an area of the scalp, and sometimes also the region about the ear, may become exquisitely tender to light touch as the result of inflammation in the throat, nasal passages or upper teeth. The term paresthesia is applied to such perversions of sensation as when one feels that the skin is swarming with insects. Paresthesias are particularly marked in persons addicted to cocaine and other narcotics.

Itching is a sensation which arises from the irritation of the nerve endings of the skin which are receptive to pain. It may occur from purely local causes such as the bites of insects. In other cases the itching may arise from no apparent cause in the area affected; it is then spoken of as pruritus. Pruritus sometimes occurs in such conditions as jaundice and diabetes.

Senses of Taste and Smell.

By means of the sense of taste we learn the character of solids and fluids taken into the mouth; by the sense of smell, the nature of the substances in the atmosphere entering the nasal passages. Taste, as we commonly think of it, does not arise solely from the mouth, but is largely a matter of olfactory impression. The true sense of taste is capable of recognizing only four characteristics of soluble substances placed in the mouth: sweet, bitter, acid, and salty. All other "taste"

impressions, and this includes the flavors that give the delicate distinction to foodstuffs, arise from the sense of smell.

The organs of taste reception in the mouth are located largely on the tongue. The tongue is dotted, particularly at the edges, with minute saccules or goblets, open to the surface through small pores and containing nerves which end in receptor organs. To arouse the sensations of bitter, sweet, acid or salt, the substance dissolved in water or saliva must enter the pores of the taste goblets and act upon the receptor organ. Insoluble substances, which are without smell, are "tasteless." When the tongue is coated, "furred" as it is called, entrance to the sensitive goblets is partially blocked and the sensation of taste is dulled.

The nerves upon which odors make their impression are in an area about one centimeter in diameter in the upper part of the nasal passages. These nerves are exquisitely sensitive to excitation by a great variety of chemical substances. In order that a substance may arouse the sense of smell it must be present as a vapor in the air drawn over the olfactory nerves. It follows that only volatile substances possess odor. So minute is the amount of certain substances necessary to arouse the sense, that for a long time it was believed that the excitation resulted from vibrations from the odorous substances, and that smell was analogous to the sense of hearing. The chief support for this view was that, with such strongly odorous substances as musk, no loss in weight of the material could be determined with the balance. Methods more delicate than the balance have demonstrated, however, that these substances do gradually pass into a state of vapor when exposed to the air.

The fact that no appreciable loss in weight was noted can be understood when we consider the extreme sensitivity of the olfactory nerves; thus $\frac{1}{25,000,000}$ of one milligram of allyl mercaptan (the odoriferous principle of the skunk) in one liter of air has a perceptible odor. The sense of smell is not equally sensitive to all substances; the threshold value varies with the material exciting the sense. The extreme dilution of the mercaptan which can be smelled may be compared with concentrations of other well-known substances as follows: essence of orange, $\frac{1}{20,000}$ mg.; ether, $\frac{1}{2000}$ mg.; and camphor, $\frac{1}{200}$ mg., per liter of air.

The nose is in open communication with the throat, and odoriferous substances can pass upward from the back of the mouth to the olfactory

area. While food is being masticated vapors pass into the throat and are carried upward by the air expired through the nose. The movement of swallowing shuts off the communication between the nose and throat, and the sensation of "taste" ceases, except as it is derived from the tongue. Flavored liquids are "tasted" at the completion of swallowing rather than while they are in the month. A judge of fine wine, or tea, or other aromatic substance, sips it, draws his breath in over his tongue moistened with the substance, and then exhales through his nose. Thus only are flavors to be fully appreciated. It is a common observation that the sense of taste is blunted when the nasal passages are partially occluded by a severe cold.

Hearing.

By the sense of hearing we become aware of vibrations within a certain range in the surrounding air. The perception of these vibrations we interpret as sound. Sounds are classified under two broad types: noises and musical tones. Noises are produced by waves which have no regularly repeated movement; their action upon the organ of hearing is in the nature of an irregular series of concussions. Musical tones, on the other hand, are caused by regular periodic aerial waves. The qualities which distinguish musical tones are loudness, pitch, and timbre. Loudness is determined by the amplitude of the sound waves which reach the ear. The greater the distance from the source, the fainter the sound, for loudness varies inversely as the square of the distance. The pitch of a tone is determined by the number of vibrations which the sound wave makes per second. The greater the frequency the higher the pitch. The form of the sound wave has no influence upon either the loudness or the pitch of a tone, but determines the character of sound known as timbre. By variation of timbre we are able to distinguish between different human voices and different musical instruments. A note struck upon a piano is readily distinguished from a note of the same pitch and loudness played upon a flute. The dissimilarity lies in the difference in configuration of the individual sound waves from the two sources. Only a comparatively few sound waves show a true sine curve when they are reproduced graphically. The proper sound of a tuning fork gives a curve of this type. Most tones are compound, that is, the simple form of the curve is distorted by overtones or partial vibrations. Overtones are produced by independent vibrations arising from segments of the sounding body. These vibrations are superimposed upon the

basic sound wave. The variety of overtones in any compound tone establishes its timbre.

The ear is not able to recognize all rates of vibrations. Frequencies below and above certain limits are not heard. These limits vary in different persons. The most sensitive ear can perceive vibrations at a rate as low as 15 to 30 per second and as high as 50,000; the usual range, however, does not extend much beyond 24,000. Sound begins to assume a definite musical character at 40 vibrations per second. The whole

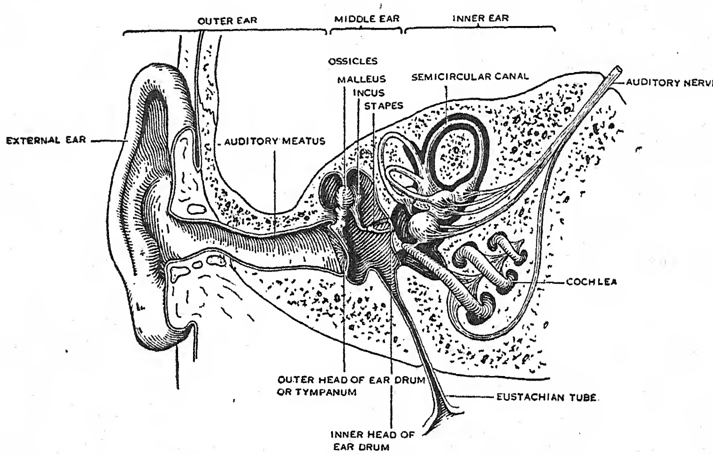


Figure 55. Longitudinal Section of Ear. (Schematic)

range of human hearing is covered in the most favorable cases by 12 octaves; for a rise of one octave the rate of vibration is doubled. In music only about 7 octaves (from 40 to 4700 vibrations per second) are used. It is probable that some animals—the cat, for example—can hear sounds too high-pitched to be perceived by the human sense of hearing. The bat, flying in the dark, avoids obstacles by the echo of a high note which it emits.

Inner Ear.

The mechanical energy of sound waves is small; and the nerve endings, which are stimulated by this energy to transmit nerve impulses, must of necessity be extremely sensitive and delicate. They cannot be exposed to the vicissitudes of the body surface; they must be firmly based to prevent jarring, and yet be in sufficient connection

with the air to have freely imposed upon them even the most minute movements of the sound waves. All these conditions are fulfilled in the human ear. The true receptive organ is buried deep in the massive bone at the base of the skull. It consists of a canal in the bone, curved and wound into the shape of a snail shell and called the cochlea. The large end, corresponding to the opening of the snail shell, is not covered with bone, but is closed with a thin membrane. The canal is filled with fluid and is lined with the delicate nerve endings which receive the energy of sound. Vibrations imparted to the fluid excite the particular nerve ending corresponding to that frequency, and the sensation of a definite tone is experienced. The fluid in the canal can be set in vibration by sound waves transmitted through the bone of the skull. Thus a sound is "heard" when a vibrating body is held between the teeth or pressed against the head. Many persons can hear by bone conduction who are deaf to sounds transmitted through the air. Their deafness is due to disarrangement of the accessory apparatus of hearing (described below), which is necessary to transmit the mechanical energy of the air waves to the receptive organ buried deep in its bony cavity.

The semicircular canals, which are organs of equilibrium, are in close connection with the inner ear. These structures and their functions, together with the sense of position, will be discussed in Chapter XVI.

Middle Ear.

The membrane covering the opening of the inner ear separates it from another cavity in the bone known as the middle ear. The middle ear is filled with air. The outer side of this cavity, like the inner, is closed with a membrane; hence the name "eardrum" is often applied to the middle ear. The outer membrane, or tympanum, is a much larger, thicker and tougher membrane than that directly opposite which covers the inner ear. The tympanum is in contact with the surrounding air, for it is placed across the end of the canal leading into the side of the head. This external canal and the aural appendage around it constitute the external ear. The cavity of the middle ear is lined with mucous membrane, and is in communication with the back of the nasal passages through a small canal, the Eustachian tube. The middle ear is essentially a sinus.

Sound waves striking upon the tympanum cause it to vibrate. These vibrations are transmitted to the membrane covering the inner ear by a system of minute bones acting as levers. The fluid of the inner ear is thus set in motion by the vibrations striking the tympanum. The three

bones which form the levers for conducting the force of the sound waves through the middle are called, from their shapes, the malleus, or hammer; the incus, or anvil; and the stapes, or stirrup. The handle of the malleus is attached to the tympanum, and its head to the body of the incus. The hammer and anvil at their junction move upon the upper wall of the cavity as a fulcrum. The stapes serves to connect the tip of the incus to the membrane of the inner ear. Excessive motion of the lever system is restrained by ligaments attached to the bones and anchored in the sides of the cavity.

Outer Ear.

The outer ear is made up of the appendage known as the pinna or concha, from which a passage leads to the tympanum. The concha serves little function in man except that of decoration; the passage, on the other hand, fulfills the important purpose of protecting the membrane of the eardrum. The canal extends inward obliquely, and projectile bodies entering the ear strike against the walls and are stopped. In its center the canal is slightly constricted so that foreign bodies inserted into the ear tend to stop midway. The walls of the canal are lined with hair and secrete a thick yellow wax, both of which tend to discourage the entrance of insects. In spite of these obstacles, however, insects occasionally find their way into the canal and may even reach the tympanum. They can at times be attracted out by holding a bright light at the opening of the canal. If this procedure fails, oil or water heated to approximately body temperature (but no warmer) should be poured into the ear and the insect thus drowned and floated out.

In some persons there is excessive formation of ear wax. Attempts to remove it with a hairpin, twisted end of a towel, or other homemade surgical instrument cause it to form in pellets, which are pushed in against the tympanum. Temporary deafness is sometimes caused by the plugging of the canal with wax. If the secretion is out of reach of the index finger it should be removed only by a physician. Personal attention to the ear should be limited to regular cleansing of the concha for cosmetic reasons. There is a wise adage that "nothing smaller than the elbow should ever be put into the ear."

Deafness.

The acuity of hearing diminishes with age, especially after thirty; the main loss is for sounds at the higher frequencies, hearing remain-

ing normal for the low frequencies. The common type of deafness results from interference with the conduction of sound across the middle ear. The inner ear retains its perceptive ability and sounds can be heard by bone conduction. Individuals so affected can usually obtain satisfactory hearing by means of the portable audiphone which is constructed on the principles of a telephone; the receiver imparts the vibration of the sound waves to the skull near the ear. Conduction deafness results most commonly from chronic inflammation and scarring of the structures of the middle ear as a consequence of infection carried from the throat through the Eustachian tube.

In order that the tympanum may function, it is necessary that the air pressure on each side of it should be equal. The air pressure within the middle ear is regulated by the Eustachian tube, which communicates with the throat. The Eustachian tube is closed during quiet breathing, but is opened during swallowing, talking, or when a deep breath is taken. Opening as it does into the throat, the Eustachian tube is frequently involved in head colds and other infections of the nose and throat. Temporary deafness may then occur because of the fact that the Eustachian tube cannot open to equalize the air pressure in the middle ear. In consequence the tympanum is pressed out of shape and the acuity of hearing is dulled; the condition is sometimes accompanied by the sensation of "ringing" in the ears.

The infection from the nose and throat may travel up the Eustachian tube. Forceful blowing of the nose, especially if both nostrils are compressed, may drive pus into the tube. Middle ear infection is painful, and if the cavity becomes filled with pus it may be necessary to drain it by puncturing the tympanum. If untreated, the tympanum may be ruptured by the pressure of the collected pus. An attack of middle ear infection does not necessarily cause deafness. The puncture made in the drum to drain the pus ordinarily heals quickly; an opening may persist after rupture of the drum but may not result in deafness unless the ossicles are damaged. It is chronic infection of the middle ear rather than acute attacks that leads to deafness. Often this infection gives rise to few symptoms except the diminishing hearing, and no severe ones as in the case of acute infection.

The greatest danger from acute infection of the middle ear lies in the possibility of the inflammation extending into the air cells of the mastoid bone. This bone forms the ridge which can be felt on the side of the head directly behind the external ear. The mastoid bone is outwardly solid; but it contains cavities connecting with the middle ear.

Pus forming in these cavities cannot drain well, and in infections it is frequently necessary to perform a "mastoid operation" in which the diseased region in the bone is removed.

The tympanum is sometimes ruptured by the concussion of explosions. In children this rupture may result from a blow with the hand over the external ear, "boxing the ears." The same corrective measure applied to other portions of the body is equally effective morally and less dangerous.

Deafness due to disease or defect of the inner ear is far less common than that due to loss of conduction through the middle ear. In inner ear deafness the audiphone gives no assistance, for the perception of sound is lost. This type of deafness may appear at birth, usually as an hereditary defect; the child so affected may not learn to talk and becomes a deaf-mute. The inner ear or its nerve to the brain may be damaged by infection, particularly scarlet fever, measles, meningitis and syphilis. The inner ear may also be injured by fracture of the skull and by the force of explosions; occasionally the inner ear is injured by large doses of drugs, such as quinine. In some cases the deafness develops gradually for no known reason. Lip reading, which with practice becomes a highly developed accomplishment, and sign language are the only means of communication with those whose total deafness is due to disease or defect of the inner ear.

An unpleasant buzzing, whistling or roaring sound called tinnitus may accompany disturbances in the ear. It may follow the blocking of the Eustachian tube and it may also be a distressing and more permanent complication of disturbances in the inner ear. When from this source the sound is often associated with dizziness, vertigo. Temporary tinnitus and vertigo may develop as complications of such infections as influenza.

Sight.

From every standpoint sight is the most important of the senses. Those whose sight is impaired to any extent are correspondingly handicapped for most occupations. The eyes are delicate structures; yet in order to perceive light they are placed in an exposed position and are therefore frequently subject to accidental injury. The eyes are also complicated structures which require accurate coordination of the various parts. Sight, more than any other sense, can be subjected to measurement and comparison in order to determine its defects. Whether we see far objects as well as those which are near; whether the printed page is blurred and a headache results from a period of close observa-

tion; whether shapes and colors are perceived correctly—such questions lead to evaluation of the individual's sight. Defects are common, as shown by the number who wear eyeglasses. Nevertheless, it is likely that the sense of sight is subject to no more frequent individual defects than the other senses; it is simply that in almost every act we are dependent upon sight, and that its improper functioning, unless corrected, is a tremendous handicap. Thus we have learned that many children, and even workingmen, who have been accounted stupid and clumsy, are so because of poor eyesight and are greatly improved when this defect is discovered and corrected.

What is commonly called the "sensation of seeing an object" is in reality not a simple sensation, but is a perception built up in the brain out of a vast number of separate sensations, and interpreted on the basis of past experience. At the back of the interior of the eyeball is a sheet of tissue known as the retina. It is like a mosaic on which each particle of the pattern is a nerve fiber terminating in receptors sensitive to light. When light strikes upon the receptors an impulse is transmitted in the nerve fiber to the brain; the impulses in each fiber produce a separate and individual sensation. The sum total of all of these sensations blended together forms the perception and thus the idea of the object which we see.

Light rays emanating or reflected from an object become more and more divergent the farther they proceed; in order to form a picture of the object upon the retina the light must be collected by refracting its rays in such a manner that they will focus upon the retina. This purely optical function of the eye is carried out in essentially the same way as in a photographic camera, by a system of lens surfaces or refracting media and a diaphragm. By varying the curvature of the surfaces, near or far objects are focused upon the retina. By varying the diaphragm the intensity of the light admitted is to some extent adjusted to the conditions of illumination.

The common defects of vision are the results of imperfections of the optical system, and not of the retina, which, like the inner ear, is a remarkably perfect structure. Accidental injuries to the retina are much less common than are those affecting the optical system in the front part of the eye.

Structure of the Eye.

The eyeball is lodged in a bony receptacle, the orbit, which is cup-shaped. The walls of the orbit are thin, except at the margins, which are dense and strong. At the upper margin the skin is augmented by a

cushion of hair, the eyebrow, which serves also to shed perspiration. Within the orbit the eyeball is bedded upon a layer of fat which allows free rotation of the globe. Six muscles extend from the walls of the orbit to the eyeball, and by their action impart lateral, vertical and rotatory motions to the eye. The muscles of both eyes normally work in close adjustment with one another. Any incoordination in muscular action results in a squint or "crossed eyes," and also in double vision.

The movements of the lids are performed almost entirely by the

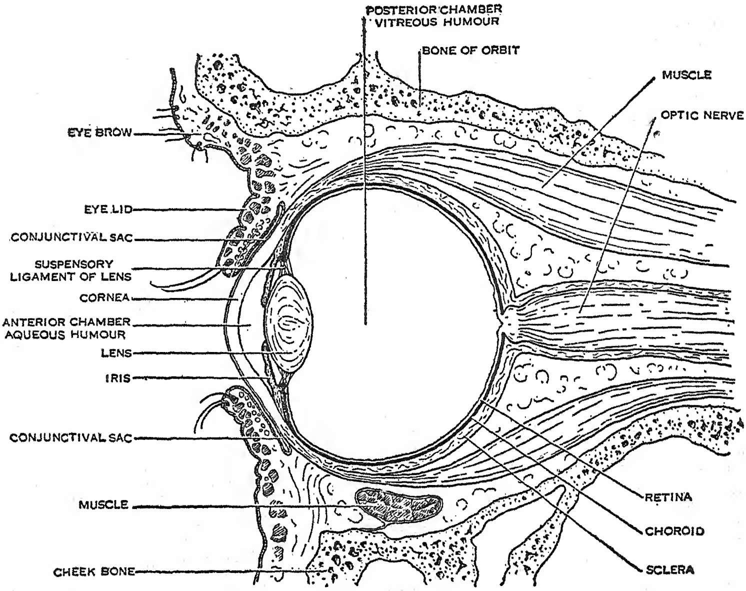


Figure 56. Vertical Section Through Eye and Orbit.

upper lid; the lower is nearly stationary. In certain diseases the upper lid becomes partially paralyzed and droops; this condition called ptosis, gives to the face an expression of drowsiness and necessitates throwing the head back to enable light rays to gain entrance to the pupil. Similarly, the lower lid may relax and allow the tears, which are constantly secreted, to spill out across the face.

The inner surface of the lids is covered with a delicate tissue, the conjunctiva. This membrane is in the form of a pouch attached around the front of the eyeball, and turned back upon itself to line the insides of the lids. The conjunctiva covering the lids rubs against that upon

the eyeball, and these friction surfaces are lubricated by a continuous flow of tears. The gland—a separate one for each eye—which secretes the tears is located in the upper part of the orbit on the side away from the nose, and resembles a small salivary gland. It pours a slow stream of fluid beneath the lids at the outer and upper corner of the eye, so that the secretion runs across the whole surface of the eyeball and finally collects in the trough formed by the lower lid. Two minute openings at the inner junction of the lids lead into a tube ending in the nose; this channel normally drains away any excess of tears. Flooding of the drain occurs when the formation of tears is excessive, either

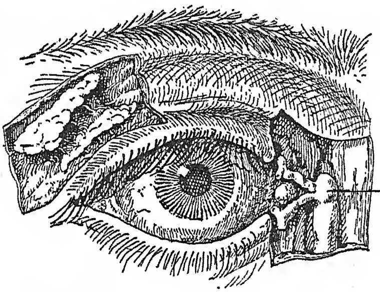


Figure 57. Lachrymal Apparatus.

The lachrymal gland, shown in the dissected area at the outer and upper side of the eye, pours its secretion over the front of the eyeball. The secretion is collected in the trough formed by the lower conjunctival sac (see Figure 56), from which it is drained through the tear duct into the nasal passage (see also Figure 33).

from emotion or from an irritation of the conjunctiva. The secretion first drips from the nose and incites the snuffling which accompanies weeping. When this normal channel of escape becomes insufficient, fluid overflows the trough of the lower lid and courses down the cheeks as tears.

Beside their function of lubricating the surface of the lids and eyeball, the tears in their natural course serve to wash dust and larger foreign bodies from the surface of the eye to the opening of the drain. This action accounts for the accumulation of dirt at the inner corner of the eye which follows some hours after exposure to dust or smoke. The tears contain an antiseptic substance which normally is capable of destroying most of the ordinary sorts of bacteria that reach the eyeball or conjunctiva. The antiseptic substance is known as lysozyme (see page 224).

The eyeball itself is spheroidal in form, about an inch in diameter,

and somewhat longer in its anteroposterior than its vertical axis, because of the fact that the front protrudes as if a section of a smaller sphere were here added on to the larger sphere. In structure the eyeball is a tough sac filled with a gelatinous material. The sac is transparent only in a small area at the front, and at this point are placed a lens and a diaphragm. The posterior half of the inner surface of the wall which forms the sac is lined with the retina, containing the receptor organs sensitive to light. The nerve fibers leading from these sensitive areas are collected in a common trunk, the optic nerve, which emerges from the back of the eyeball and passes out of the apex of the orbit to its connections in the brain.

The outer layer of the eyeball is a tough membrane known as the sclera, the so-called "white of the eye." Lining the inside of the sclera is a dark-colored coating, the choroid, which forms the base upon which rests the light-sensitive retina. To the outside of the sclera are attached the muscles which move the eye. In the center of the front of the eyeball the sclera is transparent, bulges out as mentioned above, and forms the cornea, or horny window of the eye.

The lens of the eye is placed close behind the cornea. It is biconvex like an ordinary magnifying glass, but is of such consistency and elasticity that its curvature may be altered. A thin but strong membrane is attached all around the edges of the lens, and is in turn fastened at its periphery to the inner surface of the choroid near the edge of the cornea. The membrane attached to the lens is elastic; by its pull it tends to make the lens less convex and therefore of longer focus. A series of delicate fringe-like muscles stretch from the middle of the membrane and, passing forward, are attached to the choroid. When these muscles pull they draw the elastic membrane forward and thus oppose the tension which it exerts upon the lens. Being thus partially relieved of its lateral pull, the lens assumes a more nearly spherical shape and gives a nearer focus.

The amount of light which is admitted to the lens is regulated by the diaphragm, or iris. This structure is an opaque membrane with a central opening which forms the pupil. The iris contains muscle fibers by the action of which the size of the aperture is regulated. The color of the pigment cells in the iris determines the so-called color of the eye. In albinos the pigment is absent, and a pink hue is imparted to the iris by the blood-vessels in the choroid coat. Most eyes are bluish at birth; the commencement of permanent coloration takes place about the sixth week. Exposure to bright light before this time is harmful.

The lens and its supporting membrane divide the eyeball into two compartments—the small anterior chamber and the large posterior chamber. The anterior chamber consists of the space between the lens and the domed surface of the cornea. It is filled with a fluid, the "aqueous humor." The space behind the lens, the posterior chamber, is filled with a firmer jelly-like substance called the "vitreous humor." The aqueous humor is slowly but continuously secreted and drained away and the pressure within the eyeball is thus maintained uniform. Interference with the proper drainage leads to a serious condition known as glaucoma which will be discussed later.

Accommodation to Light.

The eye, in serving the function of vision, must adapt, or accommodate, itself to great differences in intensity of light and to great differences in distance of the object seen. The range of light intensity, even under ordinary conditions, varies as much as a millionfold; at night, with starlight bright enough to show the way in walking, the illumination is a small fraction of a foot candle;[1] on a sunny day indoors ten feet from a window, where reading can be done in comfort, the light may be ten foot candles; outdoors, but in the shade where reading is again comfortable, it may be as much as 1000 foot candles, and in open sunlight, perhaps 10,000.

The changes in the size of the pupil of the eye brought about by the iris provide only a small adaptation to this wide variation in intensity of light. The largest size to which the pupil can be expanded is no more than twenty times the area of the smallest size to which it can be contracted. Moreover, with age, the pupil becomes smaller. Thus under the same intensity of light it has about half the area at fifty years as at twenty. Its range of variation in size is correspondingly lessened; elderly people are thus largely deprived of the advantage of light regulation by the pupillary adjustment; they are particularly handicapped in dim light.

The retina itself effects most of the accommodation to light intensity. The receptor organs in the retina are of two sorts, designated according to their shapes as rods and cones. It is estimated that there are about 130,000,000 rods in the retina and 7,000,000 cones. In the small central area of the retina devoted to acute and detailed vision only rods are present; everywhere else both the rods and cones are together, with, of course, the former predominating. The rods function particularly

[1] See page 398 for definition of foot candle.

well at low levels of illumination as in twilight; under such conditions neither detail nor color can be seen. The cones function best under bright light for perception of both color and fine details. When the intensity of light on the retina is increased the cones shorten and the rods increase in length; at the same time chemical alterations occur in the retina, making it less sensitive to light. These changes are not instantaneous, so that in passing from a semi-darkened room to one brightly illuminated the light is for a short time painful; but as the retina makes its adaptation vision is accommodated to the new level of intensity. In returning from the brightly lighted to the dimly lighted room adjustment must again be made before objects become clearly visible. Accommodation to bright light occurs rapidly during the first thirty seconds but is not completed for nearly ten minutes; maximum sensitivity to dim light is not attained for more than a half hour. The delay in adjustment to different light intensities has an important bearing on the occurrence of accidents, particularly in homes and factories. During the momentary loss of vision while passing from one light intensity to another the individual is, as far as his own safety is concerned, no better able to prevent accidents than a blind man. This danger can be minimized by supplying good illumination in halls, stairways and other passages which are entered from brightly lighted rooms.

Accommodation to Distance.

Light rays coming from a source at a distance greater than fifteen or twenty feet are nearly parallel. When the eye is at rest these parallel rays are refracted, that is, bent, by the surface of the cornea and lens to such an extent that they focus upon the retina. When the source of light is at a distance less than fifteen feet, the rays entering the eye are definitely divergent and must be more strongly bent in order to be sharply focused.

By "accommodation for distance" is meant the alteration in the refracting system of the eye through which divergent rays from near objects are bent to the exact degree required to form a sharp image upon the retina. In a photographic camera accommodation, or focusing, is obtained by altering the distance between the sensitive plate and the lens. In the eye the same end is effected by changing the convexity of the lens and thus altering the refracting power. The increase in the curvature of the lens is accomplished, as already explained, by the

pull exerted by a ring of radiating muscle fibers, the ciliary muscle, upon the membrane which is attached about the margin of the lens. The action of the muscle is opposite to the pull of the membrane, and so relieves the lateral tension upon the lens, which then by its own elasticity becomes more spherical. The important point in regard to accommodation is that, in order to see near objects, a muscular exertion is required; the nearer the object the greater the exertion. Any performance involving the action of a muscle may lead to strain and fatigue.

When the eye accommodates to a near object the iris constricts to make the pupil smaller even though the intensity of light acting on the eye is not increased. With a small pupil a sharper image is formed on the retina than with a large one; this is an advantage, for close work involves fine details. The constriction of the pupil necessitates a greater illumination for close work than for distant vision.

With advancing age the ability to accommodate steadily declines. A child of six may accommodate accurately to objects only three inches from its eyes; in doing so it will of necessity move both eyes inward and so appear cross-eyed. The fact that a child can accommodate to such near vision does not signify that it is a good practice to allow it to do so. The eyes will become strained and the convergence may predispose to the development of a squint. It is desirable that toys or books should be held at least twelve inches from the eyes. With age the crystalline lens loses its elasticity, so that even when the tension of the marginal membrane is decreased by the pull of the ciliary muscle the lens does not assume a more spherical shape. The power to see near objects distinctly and to read ordinary print is thus lost, while distant objects are still seen clearly and without effort. This loss of power of accommodation is known as presbyopia. By forty years of age about half the power of accommodation has been lost; usually it is still possible to read without special glasses. After this age presbyopia develops rapidly; on the average, 70 per cent of the power of accommodation has been lost at forty-five years, and 90 per cent at fifty. For most individuals reading glasses that magnify slightly and hence compensate for the flatness of the lens become necessary in the middle forties; if glasses are being worn to correct some error of refraction, either two pairs—one for near objects and one for far—or else bifocal glasses must be used. Bright illumination for near work tends in some degree to compensate for presbyopia; dim light accentuates the failure of accommodation.

The speed of accommodation diminishes with age. In the average individual about 1.5 seconds is required to make the adjustment as between near and far objects. In some the time may be as short as a second and in others it may exceed two seconds. This time is of importance in many industrial occupations, in sports, and particularly in driving an automobile. After a glance at the speedometer, one to two seconds must elapse before objects on the road ahead of the car can be seen sharply.

Visual Acuity.

The distinctness or acuity of vision is measured by the smallest visual angle at which two points can be distinguished as separate. If from the top and bottom or sides of an object which is in vision, lines were drawn to the eye, a triangle would be formed; the object would be the

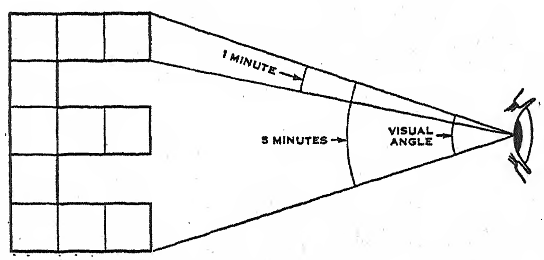


Figure 58. The Visual Angle Used in the Measurement of Acuity of Vision.

base and the two lines the sides. The angle at the apex of the triangle thus defined, i.e., at the eye, is called the visual angle (see Figure 58). The size of this angle depends upon the size and distance of the object. The greater the distance for a given object, the smaller the angle; or the larger the object for a given distance, the larger the angle. The smallest angle at which objects can be distinguished varies for different individuals, but for the average normal eye it is taken as being one minute of arc.

In conducting tests for visual acuity a white card printed with black letters and illuminated with 10 foot candles is placed before the eye, usually at a distance of twenty feet. The thickness of the detailed parts of each letter, such as the arms of the E or the legs and cross bar of the A, is one-fifth the size of the total letter. Thus a letter subtending a visual angle of five minutes has details of one minute and is therefore just recognizable by the normal eye.

A record is made of the smallest line of letters which the observer can read accurately with each eye separately. The letters on the card are designated by the distance in feet from the eyes at which they subtend an angle of five minutes. The acuity of vision is expressed as a fraction in which the numerator is the distance from the test card and the denominator the designation of the letter. Thus 20/20 vision means that at twenty feet the observer is able to distinguish letters which at a distance of twenty feet subtend a visual angle of five minutes; 20/40 indicates that at twenty feet the letters seen were those which the normal eye should see at forty feet; such vision is below normal. Often vision is actually better than the normal; the denominator of the fraction expressing acuity is then less than the numerator, i.e., 20/15 or 20/10.

Field of Vision.

A sharply defined image can be focused upon only a small portion of the retina—the region where the cones predominate. This area is known as the macula. In order to bring the image of an object upon this spot, the eyes are turned either by the pull of their muscles or by movement of the head, so that they bear upon the object. Objects outside of this direct field of vision register only upon the retina surrounding the macula and are perceived in much less detail. Such indirect or peripheral vision is particularly susceptible to moving objects; they induce a reaction by which the main axes of the eyes are at once swung toward them. Thus in crossing the street we may gaze straight to the front; but when an automobile is observed by peripheral vision or, as we say, "seen out of the corner of the eye," direct vision at once turns to the moving object. Direct vision permits the concentration of attention upon a limited field—an advantage not shared by hearing—while at the same time indirect vision acts as a sentry, causing no distraction of attention unless an object, presumably of danger, enters its much larger field. The reaction of the eye to moving objects leads to distraction of attention and ill effects to the eye itself, as when shadows from moving machinery fall across the field of a man's work or when lights move across the dark background of the working quarters. In the extreme degree, occurring in mines, this condition may result in a disease known as "miner's nystagmus" in which the eyes constantly oscillate even in daylight. The disease can be prevented by general illumination of the mine, so that there is less contrast between the moving lights of the workmen and the dark surroundings, and therefore less distraction of the eyes.

Binocular Vision.

The simultaneous use of both eyes is called binocular vision. It is by the blending in the mind of images focused upon corresponding parts of the two retinas that the brain receives only a single impression. The eyes are far enough apart so that with the gaze directed upon any near object they form the base of a triangle; this permits an estimation of distance in a manner similar to that employed by a surveyor. By such triangulation we are enabled to judge the relative distances of two objects provided they are not more than fifty feet from the observer; beyond fifty feet judgments of distance are based on sight combined with movements of the head, on perspectives, shadows, and other combinations of sensations. Beside the judgment of distance, binocular vision gives a perception of stereoscopic relations, the form and solidity of objects. Binocular vision is not developed at birth; it is acquired. The eyes of the newborn infant move independently. At the end of about five weeks the child can so move the eyes as to hold an object in the line of vision; at six months binocular fixation is acquired, and also the ability to move the eyes toward any point in anticipation of seeing something, as on hearing someone enter the room; eyesight is not fully developed until the age of six years.

Precisely coördinated movement of the eyes is essential to single vision; if the coordination fails, there is double vision and two separate images are seen. Such "seeing double" may occur as the result of intoxication in which the eye muscles as well as those of the legs lose their coordination. Likewise paralysis of one of the muscles of an eye results in squint, usually either divergent strabismus (wall-eye) or convergent strabismus (cross-eye). These conditions may develop from causes other than muscular paralysis. Unremedied squint will, if long continued, lead to impairment of vision in one eye so that finally with this partial blindness double vision is avoided. During the first years of life the purposeless movements of an infant's eyes frequently show an alarming squint. The condition is usually unimportant; it may, however, be dangerously intensified by placing objects close to the child, a natural tendency because of the shortness of its arms. Any squint that persists should receive the attention of an ophthalmologist.

Near- and Far-sightedness.

Light rays are converged by the refracting system of the eye and focused upon a point at a definite distance behind the lens. The length of the normal eye and the curvature of the cornea and lens are such

that the focus falls exactly upon the retina. All eyes are not of equal length in relation to their focal distance, some being shorter and some longer than the normal eye. In an eye of subnormal length relative to

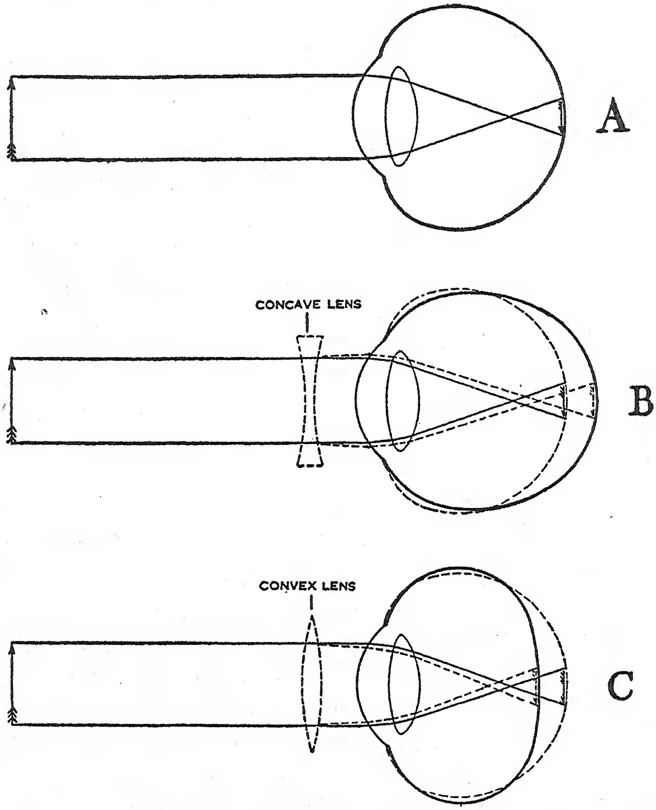


Figure 59. Correction of Eye Defects.

A. Normal eye. The image focuses upon the retina.
B. Nearsighted (myopic) eye. The eyeball is long and the image is brought to focus in front of the retina, that is, in the position of the normal retina as indicated by the dotted line. A concave lens of proper curvature restores the focus to the retina.
C. Farsighted (hypermetropic) eye. The eyeball is short and the image is brought to focus behind the retina, that is, in the position of the normal retina as indicated by the dotted line. A convex lens of proper curvature restores the focus to the retina.

its focus, the parallel light rays from a distant object are focused behind the retina, diverging rays of near objects are focused still farther back, and only converging rays can be correctly focused. The short eye is therefore farsighted, or hypermetropic. In an abnormally long eyeball

the point of focus for parallel rays is in front of the retina, and only the diverging rays of near objects can be brought to bear upon the retina. The long eye is nearsighted, or myopic.

The individual who is farsighted and who has not developed presbyopia can usually obtain clear vision by increasing the curvature of the crystalline lens and bringing parallel rays to a shorter focus. The effort of accommodation must be made even for distant objects, whereas those with normal eyes need to make this effort only to focus the divergent rays of near objects. The extra degree of effort in accommodation for farsightedness involves a constant and excessive demand upon the ciliary muscle. In young and vigorous persons the strain may be maintained for a long time without perceptible disadvantage, but in older persons whose lens have begun to harden, or in those with impaired health, symptoms of fatigue of the ciliary muscle manifest themselves. In moderate degrees of farsightedness the strain is evidenced by blurring of the type in reading. In more severe degrees the eyes may become congested, the lids and conjunctiva red and inflamed and the eye painfully sensitive to light; headache follows any prolonged near vision.

Theoretically the correction of farsightedness is simple. All that is necessary is to place before the eye a convex lens of such refracting powers that parallel rays are converged sufficiently to bring the resting focus upon the retina. Before a suitable lens can be selected, however, it is necessary to determine the degree of farsightedness. In a person of forty years of age and over, with loss of the power of accommodation, fairly suitable eyeglasses can be selected by a trial-and-error method. In order to determine the degree of farsightedness in the eye of a young person it is generally necessary to abolish accommodation by the use of a drug of the character of belladonna. A drop of the solution is placed in the conjunctival sac, from which it is absorbed into the eye, temporarily paralyzing the muscles of accommodation.

Vision is the most highly cherished sense; the correction of its errors is a serious procedure and one which should be intrusted only to the most skilled ophthalmologist. Elderly people whose only defect is presbyopia sometimes purchase suitable glasses from novelty stores or through mail-order houses, wear them with apparent comfort, and in emergencies borrow the glasses of another person similarly afflicted. Although this haphazard method of correcting refraction seems to be borne without serious harm by those whose optical errors result only

from age, it may have serious outcome when attempted by a person of less mature years.

Although the farsighted eye may often secure clear distant vision by the act of accommodation, a similar effort in the nearsighted eye only accentuates the difficulty. The myopic person is entirely dependent upon the artificial aid of lenses to see distant objects clearly. Myopia is rarely present at birth; it generally develops about the eighth or tenth year. Its appearance at that time in eyes formerly normal or farsighted is usually traceable to hereditary influences determining the shape of the eyeball, to unusual strain upon the eyes from overuse or improper conditions of lighting or posture, or to ill health. The normal eye may become nearsighted by the stretching of its coats from prolonged application to work which taxes the sight. Inefficient lighting and detailed work are therefore large factors in causing myopia. Nearsightedness tends to increase progressively from year to year up to the ages of twenty or thirty years, and in some cases throughout life. Although there may be but slight strain placed upon the mechanism of accommodation, uncorrected nearsightedness may give rise to headache and other symptoms of eyestrain.

On account of their poor vision, myopics without glasses are greatly handicapped. Individuals with this type of eye defect often manifest a strong distaste for all sports and outdoor occupations and acquire a marked predilection for indoor occupations, painting, writing, watchmaking, or other fine work. This taste is especially unfortunate, as prolonged near work aggravates their ocular deficiency. In consequence of their inability to observe the expression of those with whom they come in contact, those with myopia often develop an abstracted and even stupid expression of countenance and are frequently diffident.

Myopia demands the most careful consideration, not only by the physician, but by the layman as well. There is a more or less general impression that nearsighted eyes are stronger than others on account of ease in reading and in doing detailed work. Myopics are inclined to use their eyes at close work beyond reason. Often it may appear that the tax is without deleterious consequences, for the eyes apparently tolerate years of abuse without giving signs of failing; but by middle life the changes wrought by misuse usually manifest themselves. The prevention and correction of myopia have, therefore, a sociological as well as a medical significance.

Prevention of myopia includes an intelligent avoidance of eye strain, employment of proper lighting, and correction by glasses of any error

of refraction. Most cases of myopia develop during school age, and careful attention should be given to the avoidance of eye strain at that period of life. Many persons think that the use of glasses weakens the eyes. On the contrary, the most potent factor preventing the progress of ocular defects, once they have been initiated, is properly adjusted glasses. Errors of refraction, if permitted to go uncorrected, may increase steadily and rapidly.

Myopia is corrected by placing before the eye a concave lens which causes parallel rays to diverge. The same care in selection of the proper lens is necessary as in the case of farsightedness. Since the tendency of myopia is to increase, reexamination and readjustment of the lenses should be made each year until a comparatively stationary condition has been reached. After that, examination every two or three years is ordinarily sufficient.

Astigmatism.

Astigmatism is the name applied to an error of refraction caused by an irregularity in the curvature of the cornea. The cornea, as explained above, is the transparent area in the front of the eyeball which resembles a small watch crystal. Light rays striking the cornea are bent from their straight course and this refraction is completed by the crystalline lens. If the curvature of the cornea is regular in all meridians the light rays are bent uniformly, but if the cornea has an irregular curvature (i.e., of different radii) the light rays are unequally refracted, and are not properly focused. Details appear blurred to the eye afflicted with astigmatism; the objects are hazy about the edges just as in a photograph out of focus. If an astigmatic person closes one eye and gazes with the other at a diagram made to resemble a wheel with spokes, the spokes in certain directions appear much darker and clearer than in others.

The symptoms of eye strain are very readily induced by astigmatism in consequence of the effort made to focus rays of different length. Persons with this defect of refraction frequently contract the lids and turn the head to one side in an effort to obtain sharper vision. Headache and other forms of nervous disturbances are common. Poor vision due to astigmatism is often erroneously attributed to nearsightedness; but no form of spherical lens, either convex or concave, will improve such vision. What is needed is a glass with a cylindrical lens, which augments the refraction in the flatter meridians and thus compensates for the defects of the cornea.

The correction of astigmatism calls for great care, for faulty correction may be more harmful than no correction at all. Furthermore, glasses containing a cylindrical lens must be held firmly in the frame to prevent accidental rotation and a consequent shifting of the cylinder, which would aggravate instead of relieve the astigmatism.

Influence of Eye Defects upon General Health.

Any decided derangement in the eyes themselves or in the balance of the ocular muscles may exert an influence upon the general health. The eyes are closely connected with and are, indeed, an essential part of the nervous system; any disturbance in the eye may be referred to other parts of the system and cause malfunction in seemingly remote organs. These reflex symptoms rarely occur except in persons who use their eyes in close work for many hours each day. At times, however, they are encountered even in people who lead an outdoor life with a minimum of eye strain.

Probably the most common symptom caused by eye strain is headache. It has been estimated that nearly three-fourths of the persons who consult ophthalmologists suffer from some form of head pain. The pain of eye strain may occur in any part of the head and therefore cannot be established by its location. The time at which the headache occurs is significant, however. A morning headache is induced by prolonged use of the eyes on the previous night in one person, while in another the headache will appear in the afternoon after a day at the desk, whereas on Sundays or holidays there is freedom from symptoms. Headache can be induced by the strain of regarding distant as well as near objects. In some individuals headache appears in the morning after an evening spent at the theatre, or it may be occasioned by watching moving objects, as in crowds, or passing objects when the person is riding in a car or automobile.

Disturbances of digestion, even nausea and vomiting, are occasionally induced by eye strain. Uncorrected errors of refraction and eye strain may also have a detrimental influence upon the mental state and outlook. Pessimism, discouragement and irritability may be greatly exaggerated by the nervous strain of perverted eyesight.

Influence of General Health upon Eyesight.

Just as eye strain influences the general health, so also any diminution in general health has its deleterious action upon the eyesight. Eye strain is exaggerated by ill health, and the return of normal strength is

hindered by the continued eye strain. The eyes should be used sparingly during illness and convalescence; the muscles of the eyes are weakened during illness just as are those of the legs, but the weakness is less evident. Certain diseases have an especially weakening action upon the eyes. Of these, measles is perhaps the best known. Permanent defects of refraction may result from eye strain suffered during convalescence from this disease. Diabetes, diseases of the kidneys, and also arteriosclerosis and other disturbances may cause changes in the retina or its vessels. The ophthalmologist is sometimes the first to detect the earliest signs of these diseases, and an ophthalmological examination in which the interior of the eye is inspected is an important part of any thorough physical examination.

Eyesight and Illumination.

The blind man is an economic loss. The value of any employee, from the blind to those with normal vision, other considerations being uniform, varies with the normality of the eyesight. Besides their economic importance, the defects of vision have their sociological and humanitarian aspects. Perhaps 15 per cent of all accidents occur as a result of inability to see normally.

Illumination is an aspect of vision. The man with normal vision when placed in a dark room has no advantage over a blind man. The man with normal eyes can see the objects before him in proportion as the illumination varies from darkness to the optimum light. Lighting is therefore as important as normal vision. Indeed, in some aspects it is more so, for insufficient or poorly designed artificial lighting is an important contributing cause of defective eyesight. Some eye defects requiring glasses for correction are due to inborn malformations of the eyes, but most are acquired or at least seriously aggravated by the misuse of the eyes. The most prevalent misuse is from inadequate illumination, especially for close work.

It is incongruous that an employer, fully aware of the economic value of good eyesight, should have his offices and factories so poorly illuminated that every employee works with only a fraction of normal vision. But the matter has implications that are far more important than the economic loss; faulty illumination leads to accidents and it injures the eyes. Faulty illumination is by no means limited to industry; it is the rule rather than the exception in homes and often in schools as well.

There are two common defects of artificial illumination—glare and

inadequate light. Direct glare results when an unshaded source of light falls in the line of vision; it is avoided by raising lights so that they are well above the level of vision, or applying shades. Direct glare is immediately perceptible; the so-called indirect glare is not, but it may nevertheless be equally harmful to the eyes. It occurs when the source of light is reflected from the field illuminated, such as the page of a book, directly into the eyes. If the page is glossy the indirect glare may be detected from the presence of a shiny area difficult to read; it is not so readily perceptible on rough paper but it is nevertheless harmful. One method of detecting this injurious form of lighting is to place on the work at hand a small mirror; if the image of the light source appears in the mirror, indirect glare is present. Indirect glare occurs most commonly when the source of light, even though shaded, is in front of the work or book, as in the use of a desk lamp improperly placed. It rarely occurs when the source of light is directed over the shoulder; it does not occur with indirect illumination. The presence of glare indicates the need for rearrangement of lighting fixtures or the position of work. Reading in bed, often condemned as "bad" for the eyes, is not in itself harmful if the illumination is adequate. The ill effects commonly experienced are due to the low intensity of illumination from bedlights.

Contrary to popular belief, the strong artificial light is not harmful to the eyes. If it seems strong or is painful, these effects are due to glare. Artificial illumination used for reading in most homes and offices is usually considerably less than 10 foot candles, rarely more than 100; daylight out of doors in the shade may exceed 1000 foot candles.

The eye is so adaptable a sense organ that it cannot serve as an indicator to judge the adequacy of illumination. The retina can be forced to perform its functions in feeble light often without immediate signs of strain. But the eye under these conditions labors under a burden or handicap which will eventually prove injurious.

Illuminating rooms so that every portion is lighted to an intensity suited to close work is expensive. For this reason it is the practice to provide, first, a general illumination sufficient for good vision, and second, special sousces of illumination for close and detailed work. The general illumination prevents harmful contrasts which occur when only the work is illuminated and the remainder of the room is in shadow.

Intensity of illumination is commonly recorded in foot candles. This

unit expresses the amount of light delivered to a small area of an object held vertically at a distance of one foot from the flame of a candle. The light meters commonly used to measure the intensity of light consist of a photoelectric cell and a galvanometer; the current generated at the various intensities of light deflects the galvanometer over a scale calibrated in foot candles. Such light meters are simple and convenient to use, but they do not indicate directly the effective illumination which the eye perceives. The light reaching the eye is reflected from the surface of the objects seen; some objects reflect more light than others. Thus a white surface may reflect 75 to 90 per cent of the light, and a black surface only 1 to 5 per cent. The brightness of the surface illuminated is the fundamental feature in determining the adequacy of illumination. Brightness is determined by both the intensity of the light and the reflectiveness of the surface viewed by the eye. For adequate illumination a dark surface needs many times the intensity of light required for a white surface.

The accompanying table gives the approximate minimum desirable intensities of artificial illumination for various kinds of visual tasks.

Table XI.—Minimum Desirable Illumination for Various Visual Tasks

5– 10 foot candles	suitable for intermittent visual tasks; no detailed work as in reading or sewing.
10– 20 foot candles	suitable for offices, factories, and homes when no prolonged reading or other fine work is done.
20– 50 foot candles	suitable for ordinary reading, clerical work and sewing on light-colored fabrics. Satisfactory intensity for student in studying.
50–100 foot candles	suitable for fine work such as prolonged reading of small type, fine needlework and detailed handicraft.

A 40-watt tungsten lamp at a distance of two feet gives an illumination of 9 foot candles; a 60-watt bulb, 16 foot candles; and a 100-watt bulb, 32 foot candles. On doubling the distance the foot candle values given are reduced to one quarter since the intensity of light varies inversely as the square of the distance.

Color Blindness.

When a beam of light passes through a prism its rays are broken up into their component parts and the colors differentiated according to wave lengths. Color as such does not exist in nature, but it is a sensation excited in the eye by light waves of different lengths. Inability to distinguish all the colors of the spectrum normally visible is called color blindness.

Color blindness may be total or partial, and either hereditary or acquired. To those who are totally color-blind the world appears as though it were tinted with different shades of gray, much as in an ordinary photograph. Total color blindness is rare; but partial color defect, usually in perception of red and green, is common, occurring in about 4 per cent of all males and 0.16 of one per cent of females. Color blindness is usually an hereditary defect, and as such is a sex-linked trait; like hemophilia it occurs in the male but is transmitted by the female (see Chapter XXII). Acquired color blindness may result from any disease state which causes change in the retina or which interferes with the proper conduction of impulses from the retina to the brain. The most common causes are syphilis and the immoderate use of alcohol and tobacco; occasionally an acute infection such as typhoid fever leads to permanent disturbance in color vision. Acquired color blindness is frequently accompanied by a decrease in visual acuity; hereditary color blindness is not.

Color blindness disqualifies for all occupations in which discrimination between colors is essential. It is a prohibitive defect for locomotive engineers, for naval officers and pilots and for those whose occupations require mixing pigments or matching colors. It is an annoying and often hazardous handicap to the motorist since he is unable to distinguish the red and green of traffic lights. As a rule, those who are color-blind are unaware of their defect of vision until it is demonstrated to them by convincing tests.

Inflammation of the Conjunctiva.

In the section dealing with the structure of the eye, the conjunctiva was described as the delicate membrane which lines the lids and turns back upon the eyeball. Inflammation of the conjunctiva is known as conjunctivitis. In general, there are two types: infectious and non-infectious. Infectious conjunctivitis is caused by bacteria. The growth of the organisms upon the conjunctiva excites a secretion which varies in character according to the intensity of the infection. The more virulent bacteria induce a thick yellow discharge of pus, while mild growths occasion a mucous or catarrhal exudation. The discharge from all forms of bacterial conjunctivitis carries the infective agent. Transmission is effected by contact through soiled fingers or articles contaminated by the discharge. Non-infectious conjunctivitis results from the injurious action of irritants, such as foreign bodies, high winds, smoke, fumes and gases, and heat and light rays. Conjunctivitis may

result from uncorrected errors of refraction; this form resists all local treatment until properly fitted eyeglasses have been obtained.

Pink Eye.

Pink eye is an acute infectious conjunctivitis which occurs most commonly in the spring and fall—the season in which head colds are prevalent. Epidemics of the disease may develop in factories, schools and other institutions. The pneumococcus, the influenza bacillus, and the so-called Koch-Weeks bacillus may cause the disease. The organisms are spread from the infected eye by towels and handkerchiefs; probably also the organisms in the droplets sprayed during sneezing may, if they reach the eye, cause infection.

At the beginning of the disease the eyelids sting and itch. Next there is a discharge from the eye which glues together the eyelashes. The conjunctiva is intensely red and is swollen. The disease runs a course of ten days to two weeks and is usually followed by complete recovery. In occasional cases ulceration of the cornea results; hence the disease should always be treated by an ophthalmologist.

Granulated Eyelids and Trachoma.

In granulated eyelids, or follicular conjunctivitis, there is some reddening of the conjunctiva and sometimes a slight discharge which may glue the lids together during the night. The characteristic feature of the disturbance, however, is in the development of small oval translucent growths, granulations, upon the conjunctiva. The disease is not infectious. It is particularly prone to develop in blond individuals exposed to sun and wind, especially if they have enriched their diet with much vitamin D. Simple granulated eyelids rarely lead to any serious disturbance, but the condition may persist for a long time.

Quite a different form of granulated lid occurs in the disease trachoma. Trachoma is infectious and chronic. The granulations tend to produce scars which distort the eyelid. Severe cases may result in blindness. Under good conditions of living and with an adequate diet the disease does not tend to spread. Trachoma is a disease of poverty, squalor and crowding. It is common in Ireland and in almost all the southern European nations. It is estimated that 90 per cent of the population of Egypt are afflicted. To the traveler, one of the most striking features of the people of Egypt is the immense number who are blind and going blind. The disease was introduced into the United States by infected immigrants. In 1897 the government found the

spread of the disease from this source to be so rapid that a law was passed requiring the examination of the eyes of all immigrants, and making mandatory the deportation of persons with trachoma. The law came too late, for trachoma had already gained headway in this country. Jewish peddlers and tailors, and Italian and Slavic laborers in mines and mills have spread the disease, so that there is no part of the country where it is not found. The greatest number of cases are in the large maritime, manufacturing and mining sections. In addition to the spread of this disease among the foreign population, it has a fertile field in certain sections of the native population. Trachoma has become common among the American Indians, and the mountaineers of Kentucky, Virginia, and West Virginia. It is estimated that 20 per cent of the Indians are infected.

Ophthalmia of the Newborn.

Under the name of ophthalmia neonatorum or purulent conjunctivitis are included all inflammatory conditions of the conjunctiva of the newborn baby. In 1906 this disease was responsible for 28 per cent of all cases of blindness in the United States; by 1934, as the result of intensive effort to eradicate it, this percentage had fallen to 5.

Ophthalmia neonatorum appears usually on or before the fifth day after birth as a redness and swelling of the lids, with a discharge of fluid. The redness and swelling rapidly increase and the discharge becomes thick and abundant. On the third or fourth day of the disease the lids are so swollen that they can be forced apart only with difficulty. The eyeball is covered with a thick creamy pus. If untreated, the intense inflammation irritates the cornea, which loses its transparency and may be corroded through. In such cases the disease runs a course of several weeks, the inflammation subsides gradually and the lids are open again, but over scarred and sightless eyes. The disease is infectious; and if the discharge enters the eyes of an adult or older child, it excites an even more serious inflammation than that which affected the eyes of the newborn baby.

This distressing disease is caused by infection of the eyes of the child during the passage of the head through the vagina of an infected mother, or by infection of the eyes soon after birth by a careless nurse. The germ most frequently responsible for ophthalmia neonatorum is that which causes gonorrhea. The condition of the eyes is then really gonorrhea of the eyes acquired by the child from a mother infected with this disease at the time of the child's birth. But not all cases of

inflamed eyes after birth are due to venereal disease, for germs of a totally different nature may gain access to the conjunctiva and induce nearly the same effects. It is estimated that the germs of gonorrhea are responsible for 60 per cent of all cases of ophthalmia neonatorum; other types of bacteria for the remaining 40 per cent. Because of the uncertainty as to the cause, it is not just to brand the parents in every case of ophthalmia with the opprobrium that many persons attach to venereal disease.

Ophthalmia neonatorum is prevented by placing a drop of a dilute solution of silver nitrate in each eye of the infant within a few hours after birth. An irritation of the eyes occasionally results from the silver nitrate, for excess may do harm; and unless this condition clears up within a day or two an ophthalmologist should be called in to examine the baby's eyes. Even more important is the immediate treatment of purulent conjunctivitis if it has not been successfully prevented. Every hour of delay adds to the danger. If proper treatment can be instituted within the first day or two, sight can generally be saved.

The infection may be carried by towels, handkerchiefs, bed linen, or other articles contaminated with pus by persons with gonorrhea. The transmission of gonorrheal conjunctivitis and also of pink eye and trachoma constitutes the greatest objection to the use of a common towel. The once familiar roller towel in public places is prohibited by laws in most states, but this efficient conveyor of eye infection is still to be found in some factories, stores, and occasionally in schools.

There is always danger that persons afflicted with gonorrhea will infect either their own eyes or those of their fellow workers through uncleanliness or lack of caution. The present opprobrious attitude toward the venereal diseases makes those who are affected unwilling to disclose the fact; it is therefore impossible to control their actions by law, so as to prevent the spread of infection to their eyes and to the eyes of their associates. The only practical preventive at present is to provide every sanitary facility in urinals and washrooms. The latter should be equipped with faucets which turn on by pressure of the knee or foot rather than the hand, individual paper towels or electric drying machines, and doors fitted with kick plates instead of knobs or handles.

Sty.

Along the edges of the eyelids which hold the eyelashes are sebaceous glands such as are found with hairs in other parts of the body, and also

a row of much larger glands, called Meibomian glands, which secrete an oily material. Infection of these glands by pus-forming organisms results in the development of sties. Rubbing the eyes with the fingers to relieve the itching caused by eye strain or chronic conjunctivitis is the greatest predisposing cause to infection. A sty leads to no serious consequences but needs treatment by an ophthalmologist, especially to prevent the infection from spreading to many glands, with a consequent series of sties. Obstruction of the ducts of the Meibomian glands from inflammation may cause the retention of the secretion with a cyst-like swelling on the inside of the lid. This condition is called chalazion.

Glaucoma.

The aqueous humor which fills the anterior chamber of the eyeball is a form of lymph. It is continually secreted and drained away through lymphatic vessels. The drainage takes place through minute channels which open into the anterior chamber at the point where the outer edge of the iris meets the cornea. The proper balance of pressure within the eyeball is maintained by the rate at which the humor is drained away. In the disease glaucoma the escape of the fluid is hindered by stoppage of the drainage canals. The fluid accumulates, and the eyeball becomes tense and hard. This increased pressure is disastrous to sight, for the tissues of the eye, especially the retina and the optic nerve, cannot long withstand the pressure.

Glaucoma is a disease of middle life. It occurs in one or the other of two ways—either as a rapid or fulminating type, or in a slower and chronic form. With the acute type of glaucoma there is intense pain in the eyes. Sight rapidly decreases and may be lost in a few hours; it may never be regained unless an operation is performed at once. The chronic form of glaucoma does not give rise to pain and immediate loss of sight. The person afflicted may notice nothing more serious than headache with some difficulty in reading, which is usually attributed to the need for stronger glasses. The outcome of the condition then depends upon the type of person consulted. An optician or optometrist will often overlook the incipient disease and prescribe a pair of glasses, and perhaps a second, and even a third pair at later intervals as the loss of sight progresses. When medical aid is finally sought, after the delay caused by such refractive experiments, the disease has often progressed so far that little can be done to check it and retain even the vision that remains. Sight lost from chronic glaucoma

is never regained. If an ophthalmologist is consulted at the first indication of failing sight, he will make an examination of the interior of the eye and at once detect signs of the increased pressure. The opening in the sclera through which the optic nerve passes is the weakest point in the eye and is the first to give way when the pressure within the eyeball is increased. The ophthalmologist in making his examination will observe that the head of the optic nerve is pushed backward and a cup-like depression called "choke disk" is formed.

The operation for acute glaucoma consists in removing a segment of the iris, so that there will be a greater space for draining at its periphery. The results of this operation are often little short of marvelous. Almost normal vision is restored to eyes which have been blind for hours or days. The operation was devised in 1856. Before that time blindness from glaucoma was inevitable. The chronic form of glaucoma is usually treated with drugs which contract the pupil and thus pull the base of the iris away from the cornea, thereby exposing the drainage area. When the drug treatment fails to control the disease, an operation may be resorted to.

Cataract.

Light in entering the eye passes through the crystalline lens. If the lens becomes opaque, light cannot pass through it and vision is lost. This loss of transparency occurs in the disease known as cataract. The development of the opacity is slow and the loss of vision progressive. In its early stages the change is imperceptible to anyone looking at the eye, but in the later stages the pupil has a grayish color. A cataract should not be confused with a growth or scar upon the surface of the cornea; neither is it, as is sometimes supposed, a membrane which forms over the eyeball. It is the lens itself which changes; it is as if a clear glass lens had become frosted, but the opacity is in the substance of the lens, not on its surface.

Cataract may occur at any age, but is most common in infancy or old age. Infants are sometimes born blind because of cataract; in old age there is nearly always more or less fogging of the lens. There appears to be an hereditary tendency for the development of cataract, particularly of the type which occurs in infants. Workmen who are constantly exposed to intense light, particularly when it contains much infra-red, may develop cataract as a result. Blows over the eye and poisoning by dinitrophenol, sometimes an ingredient of "reducing medicines," may occasionally be followed by cataract. The so-called

"second sight," or ability acquired by some individuals late in life to read without the aid of glasses, is often a symptom of cataract and is due to the swelling and increase in refractive powers of the lens, which is one stage of the disease.

No medicine will cure cataract; nothing will dissolve the opacity of the lens and restore its transparency, although charlatans sometimes claim to do so. Cataract is treated by removing the lens by a surgical operation, and then fitting the eyes with spectacles having powerful convex lenses. Some measure of useful vision is thus restored; the man can see to read and to make his way about, and is capable of certain types of employment.

Foreign Bodies in the Eye.

Foreign bodies which reach the surface of the eyeball do not usually penetrate deeply into it, but are simply lodged upon the conjunctiva. Bodies of this type may move about on the surface of the eye, thus scratching the cornea and setting up inflammation often followed by infection. Infection of the cornea leads to a roughened ulcerated area which may become opaque when it heals. Scars on the cornea may permanently interfere with sight. When the foreign body is forcibly projected against the cornea and is embedded in its surface, a wound results from which the consequences are similar to those of a scratch, but more serious. Such projectiles are most commonly flying metal chips or particles thrown from an emery wheel.

Usually no serious injury to the cornea results from a foreign body on the surface of the eyeball. Serious injury and infection are, however, frequently caused by attempts of unskilled persons to remove the foreign body. Many shops boast a "handy man" who is apt at removing foreign bodies from the eyes of his fellow workers. Such a man frequently is a serious menace to the sight of those upon whom he operates. The ideal factory system is one which has an ophthalmologist or trained nurse on its staff to whom all eye injuries, even the most insignificant, are at once referred. If a freely movable foreign body must be removed without medical assistance, a clean handkerchief moistened at the corner with water, but never with saliva, should be used to wipe it off the cornea. If the foreign body cannot be dislodged from the cornea by gentle contact with the handkerchief, medical aid must be obtained. Such instruments as toothpicks, blades of knives, looped horse hairs, and the like should never be used to remove foreign bodies from the eye. Serious injury may result from such practices.

Splinters of metal are sometimes projected deeply into the cornea or may even pierce it and pass into the anterior chamber of the eye. No first-aid attempt should be made to remove such splinters. If the metal is one which responds to the action of a magnet the skilled physician will use this means to draw it from the eye. The removal of metallic objects from the eye by means of a magnet is a delicate operation. There is always the possibility that the fragment has passed entirely through the cornea and is lodged in the anterior chamber; its removal will then occasion a second and distinct perforation. Care is necessary to avoid making this wound in the optical center of the cornea, for the scar which results may then impair vision. The practice of exposing the eye to the field magnet of a dynamo or motor in a machine shop, as a means of removing steel chips, has resulted in many injuries to the eyes that could and should have been avoided.

Perforating Injuries.

The eye may be struck against any sharp-pointed tool or projection, or these may be thrust into the eye. In this field there are two chief offenders: the sharp-pointed upright paper spindle used to impale loose paper slips, and the straight-spout oil can. Injuries to the eye occur when an individual leans too close over or falls face down upon these instruments. There are many cases on record where desk workers have fallen asleep, their heads have drooped forward, and the eye has been pierced through with the paper spindle. Accidents from spindles and oil cans can be avoided by using equipment with the tips bent over instead of upright.

The greatest danger from perforating eye injuries lies in the possibility of sympathetic involvement of the uninjured eye. If one arm is seriously injured the sound arm does not in consequence become inflamed or irritated. But the two eyes are so closely bound together in their action that injury to one frequently results in an inflammation in the uninjured eye. If sight is lost in one eye through a perforating injury, surgeons usually consider it necessary to remove that entire eye. Such removal, called enucleation, stops the spread of the inflammation to the other eye and prevents total blindness.

CHAPTER XVI

POSTURE AND THE MECHANICS OF BONES AND JOINTS

ALL MOVEMENTS OF THE BODY ARE PERFORMED BY THE MUSCLES, FOR THEY are the only structures of the body capable of liberating energy in the form of mechanical work. The muscles, when stimulated, shorten along their long axis and exert a pull upon the bones to which they are attached. Although power is furnished by the muscles, they alone are not sufficient to accomplish the intricate tasks to which this power is directed, tasks which include all the arts and handicrafts that man has invented. For this purpose a system for transmitting the power is as necessary as the power itself. This system is supplied by the bones to which the muscles are attached. The bones, moving about the joints, act as levers for the transmission of the power of the muscles, and make possible the application of the power in a great variety of acts.

The Skeleton.

The bones are the only rigid structures in the body. They furnish the framework which supports the other tissues. Deprived of bones, the human body would become a shapeless, flabby mass incapable of useful movement. In the body there are approximately 200 bones of various sizes and shapes. These bones are arranged in definite relation to one another; the complete structure thus formed is known as the skeleton. Where support is the main requisite in the skeleton, the bones are bound firmly together as in the spine; when greater motion is needed, the connection is more freely movable, as between the bones of the arm.

The characteristic shape of the human body is given to it by the skeleton. The spine, or backbone, made up of a series of disk-like bones firmly bound together, connects two girdles or rings of bone. One of these, the pelvis, or hip girdle, is a ring of massive bones attaching to the spine near its lower end. The bones of the legs are attached by joints, that is, articulated, to the sides of this ring. A less complete and less massive girdle is supported near the upper end of the spine, and the bones of the arm are articulated to it. The short extension of the

spine below the pelvic girdle is of little importance to man, but in many animals it is elongated to form a tail, a structure which man has, but which does not extend beyond his surface. The extension of the spine above the upper girdle bears at its top the skull. This last structure is a rounded, bony case containing and protecting the brain. To the skull is articulated the arched jawbone. The ribs form a series of arches between the spine and the breastbone.

Development and Structure of Bones.

Development of the bones in the embryo is preceded by a deposit of connective tissue in areas which the bones are to occupy subsequently. This connective tissue is then converted into bone. The conversion commences as an irregular deposit of lime about the cells. These spicules of bone radiate in all directions from the centers of formation. At the same time, the outer layer of the connective tissue condenses to form a stout membrane, called periosteum, which is not converted into bone, but which persists as a covering for the bone. Beneath the periosteum a particularly dense layer of bone is deposited. Flat bones, such as those of the skull, when completely formed, consist of two layers of dense bone inclosing and united by a middle layer of spongy bone. The dense outer layers are covered with periosteum, and the interstices of the spongy middle layer are filled with marrow. The general structure of the long cylindrical bones of the legs and arms is similar to that of the flat bones. The bone formation, however, occurs independently in the central part or shaft, and in the two heads or ends of the bone. The spongy central mass gradually disappears from the shaft, and a cavity is left which is filled with fat. The spongy formation persists in the heads; the irregular partitions of bone run parallel to the direction of greatest stress, forming a series of reinforcing arches.

Each head of a long bone is at first separated from the shaft by a layer of cartilage called the epiphysis—a provision which makes possible a great longitudinal growth of the shaft during the early years of life. This growth is accomplished by the transformation of epiphyseal cartilage into bone; at the same time the cartilage grows and maintains its regular thickness. When the bone has reached the requisite length, the cartilage ceases to increase in substance; it is converted into bone, and the heads and shaft unite as one complete structure. In the leg bones the union of the heads and shafts does not take place until about the eighteenth or twentieth year. The lateral growth of the shafts of the long bones is accomplished by the deposit of layers of

dense bone on the outer wall beneath the periosteum. At the same time the spongy layers and part of the inner wall are absorbed. The shafts, although increasing in diameter, do not increase proportionately in weight. The pipe-like form of the long bones furnishes a much stronger structure than would a solid shaft of the same weight.

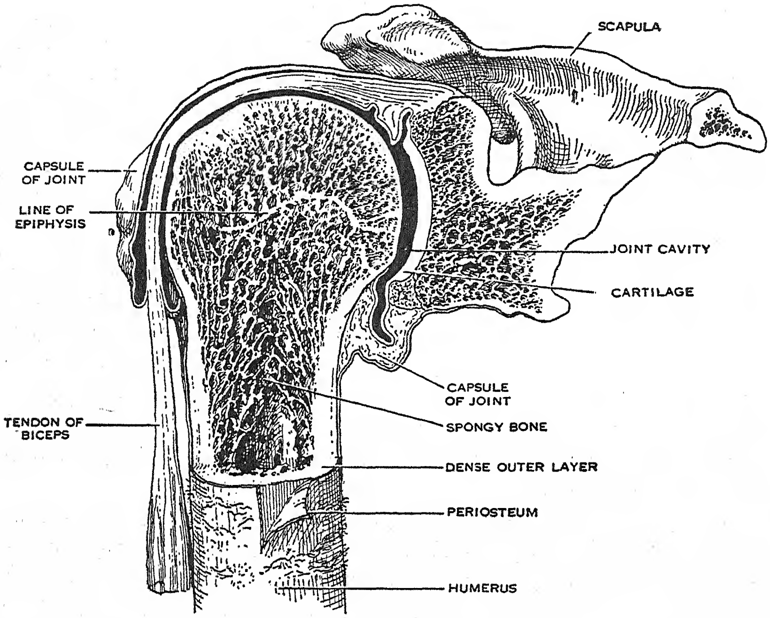


Figure 60. SECTION OF SHOULDER JOINT.

Bone Growth and Stature.

The shape and stature of the body are determined by the bones. The growth of bone is largely under the control of internal secretions from the pituitary gland. This gland, which also exercises an influence upon many other important functions, is small in size, weighing only about 0.5 gram. It is located within the skull, hanging by a slender stalk from the under side of the cerebrum and resting in a socket in the bone which forms the roof of the rear nasal passages. The pituitary gland is divided into two parts, the anterior and posterior; only the secretion of the former is concerned in growth. Removal of this part of the pituitary gland from puppies results in their becoming dwarfs. And since metabolic and sexual functions are also controlled by the pituitary gland, although through other hormones than those regulating growth,

they also become fat and their sexual organs fail to develop. In human beings disease of the pituitary gland may be followed by disturbances in metabolic and sexual functions as well as disturbances in growth. And, conversely, disturbances in the internal secretions from the sex organs may influence the pituitary and through it modify growth. Thus an increased growth of the long bones occurs in boys castrated before puberty; eunuchs therefore tend to be tall. It is possible that the development of the sex glands at puberty in part counteracts the growth hormone from the pituitary and so plays a part in slowing and finally stopping the growth of the bones. The daily injection into young rats or puppies of an extract made from the pituitary gland has been followed by an increase in growth extending in some cases to twice the normal.

In man the disturbances of pituitary secretions that affect bone growth lead to gigantism, acromegaly and dwarfism. Both gigantism and acromegaly result from overproduction of the growth hormone, usually as the result of a tumor that develops in the pituitary. Gigantism results when the overproduction occurs early in life, that is, before the epiphyseal portions of the bones have grown together. The general overgrowth of the skeleton may give a stature of seven or eight feet, occasionally even more. The arms and legs are disproportionately long; the body is usually slender.

Acromegaly results from an overproduction of the growth hormone occurring in adult life after the bones have normally stopped growing. Only certain bones respond markedly to the stimulation; stature is not as a rule greatly increased, but the hands, face and feet are affected. The lower jaw projects, the nose and lower part of the forehead are enlarged; the whole face becomes heavy in appearance. The feet and hands grow large and the fingers become broadened.

In dwarfism there is a deficiency of the growth hormone and growth is arrested, so that a true dwarf or midget results, an individual symmetrical in proportion but of a stature of only three, or at most four, feet. The head, as in the case of a normal child, is large for the body. There is also another type of bone disturbance which results in short stature, but is not related to any abnormality in the pituitary gland. The epiphyseal cartilages between the heads and shafts of the long bones fail to undergo conversion into bone; in consequence these bones fail to grow in length. Individuals thus stunted in growth do not have symmetrically formed bodies as do true dwarfs. Instead, the trunk is of normal size but the legs and arms are abnormally short.

Developmental Defects.

Numerous defects occur in the bones in consequence of localized arrest in their development before or after birth. The cleft, or dimple, in the chin is one of the commonest of these defects. The lower jaw develops in two halves which at birth are still joined in the center by connective tissue. Incomplete ossification of this connective tissue results in a depression in the chin. A similar developmental defect in the bones of the upper jaw results in the more serious conditions of harelip and cleft palate. The upper jaw and roof of the mouth are developed from a central and two lateral sections. Failure of the lateral and central sections to unite at the front of the jaw results in harelip. The name is derived from a somewhat analogous condition occurring in the hare or rabbit. Failure of the sections in the roof of the mouth to unite leaves an opening from the mouth into the nasal passages, cleft palate. Both harelip and cleft palate can be corrected in infancy by surgical operation.

Developmental defects in the bone may result from disturbance in the calcium metabolism. The commonest of these is rickets, which is due primarily to a deficiency of vitamin D. As pointed out in Chapter V, this vitamin is essential to the absorption and utilization of calcium in the body. The effects of deficiency are intensified by a shortage of calcium and phosphorus in the diet; in fact, calcium starvation, even with adequate vitamin D, may lead to changes indistinguishable from those of rickets. Rickets is a disease of the first two years of life. The bones become soft and weak; their growth is irregular; their shape distorted. A well-developed case of rickets presents an unmistakable picture. The head is large and flat on top. The ribs are roughened and feel like beads to the touch, the "richitic rosary." The chest is narrow and the abdomen protrudes. The wrists and ankles are swollen. The legs, and to a less extent the arms, are bowed. The muscles are soft and flabby. The eruption of the teeth is delayed. In less severe cases the main defect may be in the bowing of the legs; bowlegs do not result from premature standing as is sometimes believed, but from rickets. With the correction of the dietary deficiency—or with exposure to ultra-violet light—the rickety condition is healed. If it is treated early, healing may be complete; but if there is delay, bowing of the legs may persist, and in girls the pelvis may be so deformed as in later life to render normal childbirth difficult or impossible.

A condition essentially the same as rickets but occurring in adults is known as osteomalacia. Deficiency of calcium in the diet is the

primary cause, but extreme lack of vitamin D, of which adults need much less than infants, may possibly be an aggravating factor. The condition occurs most commonly in women and during the periods when they are pregnant or nursing. Their requirements for calcium at these times are especially great; if calcium is not furnished in the diet, the bones are robbed to supply the child in the uterus or the milk secreted from the breast. In osteomalacia the bones become soft and pliable; great deformity may result.

For reasons unknown, the bones may from infancy occasionally be abnormally thin and fragile. Fractures result from the most trivial injuries. Healing occurs normally, but the bone soon breaks again. A case has been reported of a girl, aged thirteen, who had suffered forty-one fractures.

In the disease called osteitis deformans, which develops only in aged individuals, the bones become abnormally dense and thickened. The skull increases in size; the back is bent and the legs are bowed.

The secretion of the parathyroid glands has an influence upon the deposits of calcium in the bones. These glands are located in the neck, closely attached to the thyroid gland. Deficiency of parathyroid secretion, as may occur acutely from injury to the glands during operations upon the thyroid, is followed by a sudden decrease in the amount of calcium normally found in the blood. A peculiar type of convulsion known as tetany (not tetanus) then occurs. Tetany may also develop in children suffering from severe rickets or in those fed insufficient amounts of calcium. Overproduction of the parathyroid secretion, usually due to a tumor in the parathyroid gland, is followed by destruction of the bones. In this rare disease the individual affected shrinks in size as his bones become thinner and smaller. If the tumor causing the disturbance can be located and removed, the condition may be arrested.

Inflammation of Bones.

Inflammation occurs in bones just as it does in any other tissue of the body; it is called osteitis. When the central cavity of a long bone is particularly affected, the name osteomyelitis is usually substituted. Three different types of changes occur in bones as a result of inflammation: (1) In rapid inflammation an area of the bone dies, and is separated from the living bone. The dead portion then becomes a foreign body in the flesh, and must usually be removed by surgical operation. (2) In less acute inflammation, and also in that resulting

from tuberculosis, the affected bone is destroyed, becoming soft and porous. This process of destruction is known as caries. Decay of the teeth, dental caries, may lead to a localized destruction or caries of the jawbone. (3) Chronic inflammation, or the healing of an inflammation, leads to a thickening and hardening of the bones, as is the case with arthritis deformans, discussed later.

Inflammation of the bone may occasionally arise from a blow over the bone without the introduction of bacteria. More often it results from infection. This infection may arise from direct contamination, as in a compounded fracture, or indirectly from bacteria carried by the blood to the bones. Tubercular infection of the bones is particularly important because it is the common cause of hunchback and hipjoint disease. Tuberculosis of the bones occurs most often in children. The bones of the spine, of the knee and of the hip are the ones most commonly affected. The caries caused by tuberculosis results in a slow destruction of the bone. When the spine is affected, the bodies of the vertebrae are softened, the pressure from the weight of the body causes them to fall together and produces a backward displacement of the spine which in its extreme form is popularly known as hunchback. After the disease has lasted from one to three years the inflammation usually ceases and repair begins. The diseased vertebrae knit together into a solid mass. The deformity caused by the disease can be limited, and in many cases avoided, by applying a properly designed support which is worn until repair of the bone takes place.

Tubercular disease of the hip, like that of the spine, gives little immediate indication of its development. If detected in its early stages, the disease can often be cured without leaving any deformity. If allowed to progress, the disease extends into the hip joint and destroys the head of the femur. This bone then grows firmly to the pelvis, so that deformity and permanent lameness result.

Fracture of Bones.

The terms broken bone and fractured bone denote precisely the same condition. Fracture usually results from some sudden external force applied to the bone, as from a fall or blow. The fracture does not always occur at the place where the force is applied. In jumping from a height the force of landing is applied at the feet, but the fracture may occur in the upper part of the legs. The bones of the legs are compressed by the force and yield at the weakest point; the direction of the fracture is determined by the direction of the stress. Fractures

may also occur from the pull of the muscles during violent effort, as in the sudden jerk made to prevent a fall. Such fractures are usually in small bones or at the prominences of bones to which the muscles are attached.

Usually a fracture is across the bone. In children, however, a bone sometimes breaks only part of the way across, and at the same time bends and splits longitudinally; this is called "greenstick fracture." Similar incomplete fractures may occur in the bones of the skull. On the other hand, when a great force is applied to a bone it may be shattered into small bits—that is, comminuted. One end of the broken bone is sometimes pushed through the skin by the force causing the fracture, as in jumping from a height. Such a fracture is said to be compounded. It is unfortunate, but often the case, that misdirected first-aid administration results in compounding a fracture. As a rule, a compounded fracture is much more serious than a simple fracture, both by reason of the hemorrhage which may result and more particularly the infection of the projecting bone by contamination with dirt. In fact, it was the observation of the frequent suppuration about the bones in compound fractures, and the absence of this complication in fractures which were not compounded, that led Lister to the doctrine of antisepsis which he introduced into surgery.

At the time a fracture occurs the person usually feels or hears something give way with a snap. At the same time pain is felt, and becomes more severe if movement is attempted. The area surrounding the fracture swells, and often the skin appears red and blotchy. Partial or complete loss of function of the part usually occurs. Movement may be accompanied by a grating sensation as the broken parts rub over each other. The abnormal posture into which a broken limb is forced is sometimes a definite indication of a fracture. The examination to determine whether a bone is broken should be carried out with great caution, both because of the pain it causes and because the fragments of the bone may be moved from their position, or even forced through the skin, thus compounding the fracture. The final determination, and in many cases the only possible determination, of a fracture is made by X-ray examination. Such examination should be made in every case of suspected fracture.

Fractured bones usually knit together when the broken ends are held in apposition. The setting or reduction of the fracture should be performed by a physician, for it must be done skillfully in order to avoid deformity. Sometimes reduction can be effected only by surgical

Courtesy Eastman Kodak Company

PLATE IX. Radiograph showing the bones of the leg broken above the ankle. The fracture has not been reduced. See page 413. The victim of this accident was young and the heads of the bones are not yet completely united with the shafts. See page 408.

operation. After the fragments are brought into the proper position they are held in place by a splint. A splint is a support of rigid material—wood, metal or plaster—fitted over the limb and extending above and below the fracture. The setting of a broken limb can be greatly facilitated by proper first-aid treatment. This treatment consists of securing the limb in a rigid position with the minimum of preliminary movement. For this purpose a temporary splint is made from any convenient stick, and to this the limb is strapped or tied, but not so firmly as to impede the circulation when swelling occurs. A broken leg may be held in position by tying it to the opposite leg. In performing first-aid work the subject should never be carried by lifting him at the shoulders and feet, until it is certain that the legs are not broken, for otherwise a fracture may be compounded during the lifting.

Fracture of the skull deserves special mention both because of its seriousness and because it is at first often overlooked. A violent blow applied to the skull fractures and depresses the bone; a less violent blow may lead to a crack in the bone which does not at once indicate its presence; nevertheless, it is extremely serious. A fracture of the skull may be produced in other ways; thus when a man falls from a height and lands on his feet, the upper end of the spine may be driven against the skull with sufficient force to crack it. Every case in which there is the slightest suspicion of fracture of the skull should be taken to the hospital for observation. Unconsciousness does not always occur in fracture of the skull and the subject may be in apparent good health for several days after the fracture. Hemorrhage from the mouth or ears after a fall or blow is a serious symptom, or it is suggestive of a fracture of the skull, as is also blackening of the lower lids of both eyes. The bleeding in these cases occurs through a crack at the base of the skull. Hemorrhage into the skull increases the pressure there. The bones of the skull cannot yield, and the brain is compressed. Death may result if the pressure is not relieved and space allowed for the swelling by a surgical operation called trephining, in which a hole is cut in the skull.

Fracture of the spine differs from other fractures for the reason that the spinal cord runs through a cavity in the vertebrae which make up the spine. Displacement or bending at the fracture brings pressure upon the cord, and causes paralysis and often death. Such fractures are difficult to treat, and in many instances do not knit, although in occasional cases complete recovery results. If there is a possibility that

the spine is fractured, great care must be taken in first-aid work in handling the injured individual; movement may force the broken bone against the spinal cord.

Joints.

The attachment or articulation of one bone of the skeleton to another is called a joint. In some of the joints the bones are locked as one piece and no movement can occur at the union; such is the case with the bones of the skull, which are dovetailed rigidly together. In other joints the bones are bound together firmly with fibrous connective tissue, and only slight movement is possible between them; such are the joints between the pelvis and the spine. Other joints, such as those of the knee, elbow and jaw, have a specialized structure which permits free movement. The ends of the two bones, meeting at a freely movable joint, are expanded and conform more or less exactly to one another in shape. That is, if the head of one bone is shaped like a ball, the other is hollowed out to form a socket. At these surfaces the bones are particularly dense and strong. Layers of cartilage cover the opposing ends of the two bones, and the cartilages in turn are covered with a thin "synovial" membrane which forms the friction surfaces of the joint. (See Figure 60.)

Ligaments bind the bones together at the joint and prevent their separation or displacement. These ligaments form a sheath or capsule about the joint. This capsule is inelastic but pliant, and sufficiently loose to allow movement. The muscles attached to the bones on each side of the joint assist in holding the bones in apposition; if a pull is made on the bones sufficient to overcome the tension of the muscles, the articular surfaces of the bones can be separated a short distance.

Dislocations.

Displacement of the bearing surfaces of the joint from their normal relation is called dislocation. Dislocations are usually caused by external force, but occasionally also by the pull of muscles. A bone which is dislocated is held in its abnormal position by the tension of the muscles attached to it. Frequently the capsule about the joint is torn, the bone may pass through the opening and so slip entirely away from the normal bearing surface.

The treatment of a dislocation consists in restoring the bones to their normal relations and supporting them in place until the injury to the capsule has healed. This setting, or reduction, of a dislocation

is best effected by moving the joint in such directions as to cause the end of the bone to retrace its course and slip back to its normal position. Reduction by this method is most easily applied to the shoulder joint. When reduction cannot be effected by manipulation, it is then necessary to overcome the muscles by force and pull the bones into place. This procedure may usually be applied safely to the jaw, which may be dislocated by opening the mouth too wide. It may be applied likewise, by one familiar with the procedure, to dislocations of the fingers; but for the thumb and any larger joint it should be performed by a physician. Considerable damage to the joint may result from misdirected and overzealous efforts at reducing by force during first-aid procedures. If the ligaments of any joint are permanently weakened by disease or stretched by repeated dislocation, the condition is commonly referred to as "double-jointedness."

Injury to the joints, particularly that of the knee, may result in the partial tearing of the cartilage from the head of the bone. The loosened tip or a piece broken off may work between the bearing surface and cause the joint to "lock." This condition is a common athletic injury.

Bursitis.

The capsules about the joints are lined with synovial membrane, which is a continuation of that covering the cartilage of the ends of the bones. The synovial membrane thus forms a sac within the joint. This membrane secretes a small amount of viscous fluid called synovia, which resembles white of egg and which lubricates the joint. A sheath similar in structure to the capsule of the joints, and likewise lined with synovial membrane, surrounds long tendons, such as those to the fingers, forming a lubricated sheath through which the tendon slides. Small closed sacs lined with synovial membrane also occur about some of the joints and over bony prominences where pressure is frequently applied. These sacs or "bursae" normally give some protection to the joints. When they are struck and bruised they may become inflamed and fill with fluid, or even pus. Swellings are formed, which are painful. This condition is known as bursitis. Repeated injury to a bursa may result in chronic inflammation; the bursa then becomes thickened and enlarged. This condition is often named after the occupation in which it occurs, as housemaid's knee, miner's elbow, tennis elbow and the "glass arm" of the baseball player. Slight but frequently repeated injuries to a joint may result in changes not only in the

bursa but in the bone; the deformity about the great toe joint called a bunion results from the injury caused by wearing short shoes.

Sprains.

Sudden stretching and tearing of the ligaments of a joint and injury to the synovial membrane, such as occurs when the weight of the body comes down upon the foot with the ankle turned sideways, is known as a sprain. The injury results from carrying the movement about a joint beyond normal limits. If the ligaments are not torn, but merely painfully stretched, the condition is sometimes classed as a strain. A sprain is associated with severe pain and is immediately followed by hemorrhage into the tissues about the joint. The area is colored bluish by the blood as in a bruise. Fluid also seeps from the blood vessels and collects in the tissues, causing swelling. The swelling can be minimized by raising the sprained joint to lessen the pressure of the blood—i.e., lying down and elevating the ankle higher than the head—and applying cold water or an ice pack. A severe sprain requires a long period of rest followed by massage and thermal treatment before the ligaments are restored to normal condition. A neglected sprain may lead to permanent weakness and chronic pain in the joint affected.

Occasionally, usually as the result of a sudden pull of a muscle with its antagonist held tense, a muscle may be torn and ruptured. Likewise in severe sprains a small piece may be broken off from the main bone by the pull of tendons; this condition is known as a sprain-fracture. It requires the same treatment as any other broken bone.

Arthritis.

Inflammation or infection of a joint is known as arthritis. The infection results from the introduction of bacteria, either through a wound into the joint, or from an extension of infection from other parts of the body. In acute infections the joints swell and pus is formed in the cavity lined with synovial membrane. Such infections may be serious because during the healing process the inflamed membrane and cartilages may be destroyed and the exposed bone knit together at the joint. Occasionally a chronic inflammation occurs in many joints and is followed by union of the bones, causing the entire body to become rigid, until the only motion left is perhaps a slight movement of the fingers and the jaws. The petrified man of the circus side show

is an example of this disease; most of the other exhibits in such places suffer from disturbance of the glands of internal secretion.

Inflammation of the joints may occur without the formation of pus, as in acute articular rheumatism, or may even arise without infection. The latter type of inflammation is centered particularly in the synovial membrane lining the capsule. Swelling results from the collection of fluid in the space of the joint, so-called "water on the joint." After passing through the acute stages, the inflammation usually subsides. The joint may have developed some limitation of movement, and may give a slightly grating sound when moved. A similar type of inflammation occurring in the sheath about the tendons is called a "weeping tendon."

"Rheumatism."

The term "rheumatism" is no longer employed by the physician, but the word continues in popular use to include pains in muscles and nerves but more particularly chronic disturbances in joints, chronic arthritis. The commonest severe muscle pains are in the small of the back, lumbago, and in the neck and shoulders; they are unpleasant but usually only temporary. Improper posture, exposure to cold and wet, infection, especially of the tonsils or sinus, and occasionally mild rheumatic fever are some of the known causes of the so-called "muscular rheumatism." Often, and for reasons unknown, the nerves to the muscles are affected and the condition is then a neuritis as well as myositis (inflammation of a muscle).

The joint "rheumatisms" are widely prevalent, leading all other chronic diseases in disability and economic loss. In England one-sixth of the industrial invalidism is due to "rheumatism"; each year it costs $25,000,000 in sick benefits.

There are two general types of chronic arthritis. In one, called rheumatic arthritis, the affected joints become swollen and are painful. Usually the condition starts in the hands and may involve only one or two joints or it may extend to nearly every one in the body. The condition stops after a short time and the joints heal, but it may also return; it may even continue progressively. If the disease persists the muscles become weakened, the bones thinned and deformed, and the joints stiffened. This type of arthritis may occur at any time of life. The second type, called arthritis deformans, begins after middle life and affects the fingers, the spine and knees. There is an excessive

growth of bone about the joints; their motion becomes limited and they feel stiff, especially after they have been held still for a time.

The causes of the disabling rheumatisms are unknown. Many physicians believe that they are due to infection. It is certain that dietary deficiency, general ill health, unhygienic living conditions and damp houses are predisposing factors. Correction of these disturbances, rest and medical care lead in many cases to considerable relief from the arthritis and may prevent disablement.

Mechanics of Bodily Equilibrium.

The body is of irregular shape and density. Its center of gravity, as in any other system of masses, is represented by a point so located that

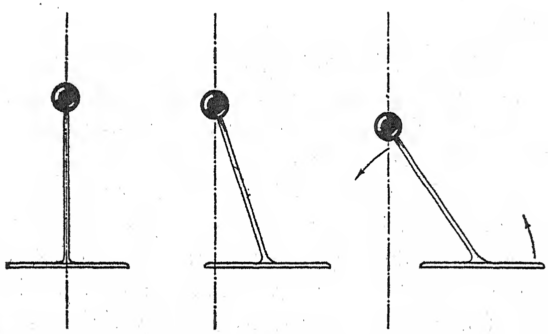


Figure 61. STABILITY IN RELATION TO THE POSITION OF THE LINE OF GRAVITY.

gravity appears to act entirely upon that point. The center of gravity may or may not be within the substance of the body. When the human body is extended rigidly and laid flat upon a board, and the board is adjusted at various points across a sharp edge, a position is found at which a balance is obtained, as in the seesaw used by children. In that particular position the force of gravity appears to act upon the body in only one place, a point directly over the sharp edge upon which the board rests. That point is the center of gravity of the body.

In the erect position the center of gravity of the body is at about the level of the navel. In this position the body is supported by a base formed by the feet and the area between them. Treating the human body as a rigid system, which it is not, we can represent it in its relations to gravity by a mass equal in weight to the body and supported by a line attached to a base, as is shown in Figure 61.

The dotted line in this figure represents the direction of the force of gravity. The mass supported will remain stationary in any position in which the line of force passes through the base. In the third diagram the line of force falls outside of the base and the mass will therefore fall over. The stability of the mass depends upon three factors: (1) the height at which it is supported above the base—the shorter this support the greater the stability; (2) the area of the base of support—the larger the base the greater the stability; and (3) the point at which the line of gravity cuts the base—the nearer the center the greater the stability.

Instead of being a rigid system, the body is segmented in structure and is flexible. In order to maintain a state of equilibrium in the erect position muscular force must be exerted internally to afford sufficient rigidity in its various parts to hold the center of gravity over the base. An unconscious man or a drunken man cannot stand, because the muscles fail to hold his body sufficiently rigid. The more stable the system, the less will be the muscular force necessary to maintain the upright position.

The Erect Position.

There are three ordinary standing positions: that of "attention," that of "at ease," and the "hunched" attitude. These three positions are illustrated in Figure 62. In both of the symmetrical positions the weight of the body is equally distributed between the two legs. In the position of attention the line extending from the center of gravity to the base formed by the feet passes to the rear of the center of the base and hence outside of the position of maximum stability. In the attitude of "at ease" the body is more stable, for the line passes through the center of the base. In the asymmetrical or "hunched" attitude the weight of the body is carried largely on one leg; the other by being put to one side makes a wide base and hence effects a greater stability even though the line of gravity falls nearer to one side of the base. Standing with the legs spread wide apart in like manner increases stability.

The degree of stability given by any erect position is reflected in the muscular energy necessary to maintain the position. The relative amounts of energy expended in sitting and in standing in the three positions described are given in the accompanying table. The figures are estimated on the basis of 100 per cent as the energy expended during sitting.

	Relative Energy Expended (approximate)
Lying	92
Sitting	100
Standing "hunched"	103
" "at ease"	106
" "at attention"	125

In movements of the body with the feet stationary, as in bending forward or backward, various segments of the body are moved to

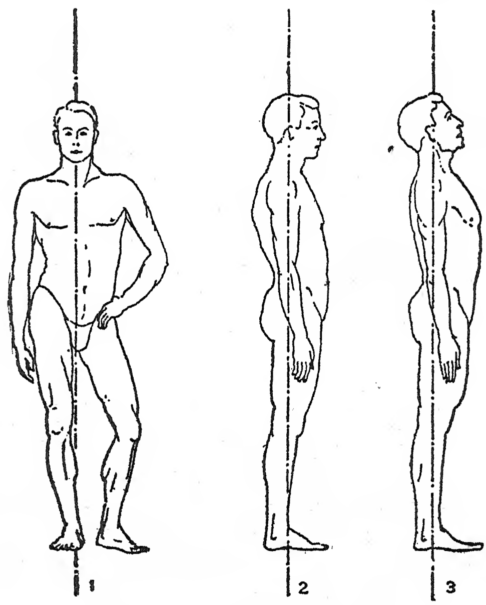


Figure 62. Positions in Standing.
(1) Hunched.
(2) At ease.
(3) At attention.

compensate for the displacement of mass, so as to keep the center of gravity over the base. Figure 63 illustrates this principle.

Any burden carried by a man becomes part of the system acted upon by gravity. The center of gravity is shifted and the position of the body is altered to bring the center over the base. A man carrying a burden in one hand leans to the opposite side and even extends the free arm for further compensation. A burden borne on the back is compensated for by bending forward. Similarly, alterations in the distribution of the mass of the body involve change in position. In pregnancy the shoulders are thrown back to counterbalance the weight of the

uterus; a similar change is seen in obese men. The hunchback must stand so as to support his center of gravity; the man bent with age has recourse to a stick in order to increase the area of his base of support.

If a man stands stiffly at attention he soon becomes fatigued. Although the energy expenditure required to maintain the body rigid

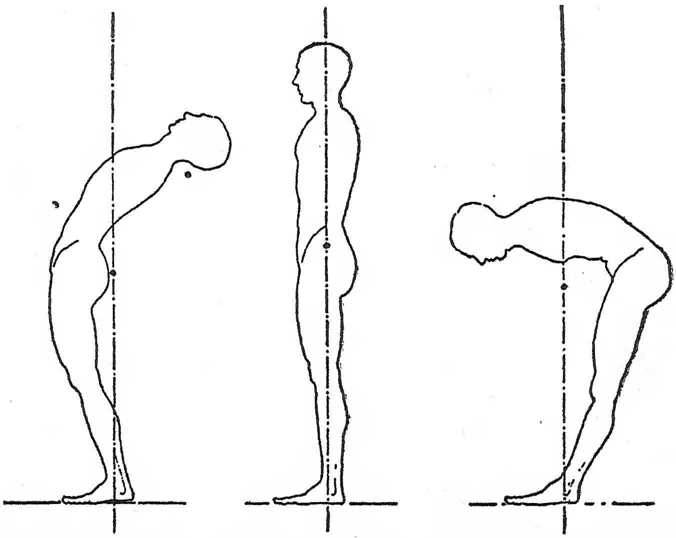


Figure 63. Change of Center of Gravity with Movement of the Body.

is not great, it is nevertheless carried out by a group of muscles acting at a great mechanical disadvantage. These muscles, in view of their mass, are making a large and sustained exertion and rapidly become fatigued. Moreover, the erect position is disadvantageous for the return of the blood through the veins of the leg, a topic discussed under varicose veins. The heart pumps less blood when the body is held erect and stationary, than it does in the sitting and lying positions, or during even moderate movement of the body in the erect position. It is not uncommon for men to faint after standing for some time in the position of attention, i.e., soldiers, or one having a suit measured and fitted. Fainting under these conditions occurs more often in young and athletic individuals than in those who are middle-aged or older.

The Senses of Position and Movement.

Even with the eyes closed we have a definite idea of the position of

our limbs. This sense of position is of the greatest importance for controlling movements and especially for muscular coordination. Through it the individual learns to what extent movements are carried out or fail to be carried out. The nerves which bring to the brain the impulses, which are there interpreted as position, have their origin in the tendons of the muscles, the joints and, to a less degree, in the skin.

The interpretation of the sensations of position and movement is derived from experience. The infant is born with these senses undeveloped, and he learns gradually as the nervous system develops. Repeated trial and error lead slowly to the association of the sensations derived from various positions with memory pictures obtained by the senses of sight and touch. The child sees its hand before its face and feels at the same time the sensations associated with this position. Repetition of the act finally results in the ability to assume this position, and to know where the hand is, without requiring the aid of sight. This ability originates in the vaguely groping movements of a young child and leads to the slow development of coordination and skill. To a considerable degree this same education of the sense of position goes on through life as new activities are undertaken. It is developed to a high degree in those skilled in such sports as tennis and baseball, and in the arts and handicrafts. In fact, learning a manual trade is largely the development of such coordination.

The position of the body is maintained by coordinated muscular activity. The muscles applying the internal forces which hold the body rigid are maintained at a steady pull. Slight displacements of the body are compensated unconsciously by changes in the tenseness of these muscles. If the body is forced far from its position it is brought back to equilibrium without conscious effort. The coordination of muscular activity by which equilibrium is maintained is effected through the nervous system under the combined influences of the sense of position, vision and the activity of the organs of equilibrium in the skull. Any two of these systems are sufficient to supply the necessary impulses to the nervous system, but at least two are necessary. The normal man can stand erect and maintain his equilibrium with his eyes shut; the organs of equilibrium and the sensation of position effect the stabilization. But the man with locomotor ataxia (see page 353) cannot thus maintain his equilibrium for, as a result of his disease, impulses are not carried to the nervous system from the muscles, joints and tendons of his legs; when he closes his eyes the one system

left operating, the organs of equilibrium, is insufficient to maintain stability.

The Organs of Equilibrium.

The organs of equilibrium are embedded in the bones of the skull and connected with the inner ears (see page 377). Each consists of three looped tubes and two small sacs. The tubes are called the semicircular canals; they lie in planes approximately at right angles to one another. The canals communicate with the sacs; and they in turn are connected to the cochlea of the inner ear. The entire structure is filled with fluid resembling lymph. On the inner wall of the expanded outer ends of the semicircular canals are fine hair-like structures, receptor organs, attached to nerve fibers; similar sensitive hairs line a portion of the surface of the first of the sacs into which the canals open. These hairs are covered with a layer of gelatinous material in which are embedded particles of lime salts. Any change in position of the head results in a corresponding movement of the fluid in one or more of the canals of the sacs; the movement of the fluid stimulates the sensitive hairs. These receptor organs have extensive and elaborate connections in the nervous system; impulses from them may be transmitted to the mid-brain, the cerebellum, the cerebrum, the spinal cord. The muscles that adjust the body's position, i.e., compensate for movements so as to maintain the center of gravity above the base formed by the feet, are influenced by impulses from the organs of equilibrium. The muscles which move the eye also receive impulses. If strong enough, the impulses may be relayed to the vomiting center in the brain (see page 39).

Seasickness and Car Sickness.

Dizziness or vertigo results when the organs of equilibrium are strongly stimulated as by rotating the body rapidly or moving it backward and forward. On stopping the motion, the stimulation persists for a short time. The eyes may be affected and move back and forth rhythmically, the condition of nystagmus. The gait is unsteady and it may even be impossible to maintain equilibrium so that the individual falls. Nausea and vomiting may occur. All of these disturbances are seen in seasickness. The vomiting in this condition, although due primarily to the stimulation of the organs of equilibrium, is influenced, as vomiting commonly is, by mental factors. The sight of someone becom-

ing sick, the smell of food or even the fear of becoming seasick may precipitate the vomiting; distraction as from interest in some task may help to prevent it. So extensive are the nervous connections to the organs of equilibrium that impulses from the eyes or stomach may disturb equilibrium. Thus the continued rhythmic movements of the eye muscles, as in looking at the scenery from the window of a moving car, may lead to nausea (car sickness), and nausea arising from an upset stomach may cause dizziness and unsteady gait.

Posture.

The posture assumed in both sitting and standing not only is a matter of esthetics, but is also of great practical importance for health and efficiency. Improper posture increases fatigue. It is also the main cause of a number of ailments; the most common are back strain and pain in the muscles of the back. It may also lead to disturbances in the function of the alimentary and urinary systems. Correct posture depends upon the manner in which the spine is held, and a consideration of the anatomy and physiology of this region is essential to a discussion of posture.

The Spine.

The spine is composed of a series of thirty-three or thirty-four bones shaped like disks. These bones are called vertebrae, and are piled one upon another. The space between adjacent bones of the column is separated by a disk of cartilage and surrounded by a capsule of ligaments, so that a joint is formed between each two vertebrae. The column of vertebrae is held in position by muscles, the loin muscles, which run up the sides of the vertebrae and are attached to them. In addition to the muscles, a series of ligaments run lengthwise of the spine and are attached to the sides of the vertebrae. These ligaments restrain the movement of the spine within certain limits. The ill effects of improper posture result in part from the strain put upon these ligaments. The extreme limit of movement of the joints of the vertebrae is fixed by processes of bone which extend from the rear of the body of the vertebrae and come in contact with similar processes of the adjacent vertebrae. The spinal column of different animals has various degrees of flexibility. That of the cat is particularly flexible.

For purposes of description the spine is divided into four segments. That portion extending through the neck is known as the cervical

spine. Its vertebrae have the freest motion. The portion of the spine which runs behind the chest is called the dorsal spine. The lateral motion of the vertebrae has there an additional limitation because of the attachment of the ribs, but rotation is not interfered with. The portion of the spine extending from the lowest rib to the top of the pelvis is called the lumbar spine. The vertebrae in this region are so constructed that bending is possible but rotation is very limited. The vertebrae below the lumbar region are fused together into one piece called the sacrum.

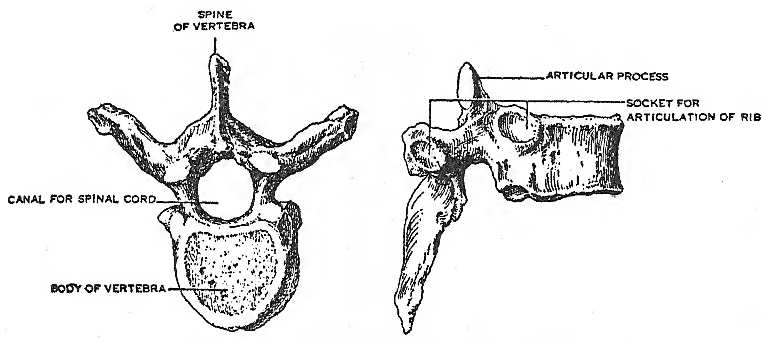


Figure 64. VERTEBRA, TOP AND SIDE VIEW.

The bones of the pelvis are joined to the sides of the sacrum. The pelvic bones form an arch with the junction of the two bones in the mid-line of the body at the lowest part of the abdomen. The sides of the pelvic bones are flared outward at the top to form the hips, and below this projection are sockets to which are articulated the bones of the legs. The sacrum resembles a keystone in the arch formed by the pelvic bones, but it is an inverted keystone, for it is narrower at the outside than at the inside. The weight of the body in the upright position tends to force the sacrum into the pelvic opening. This force is counteracted by ligaments which tie together the sacrum and pelvic bones and prevent almost all motion in this joint. The burden placed upon the ligaments connecting the pelvis and the sacrum is great; not only must they bear the inward thrust of the sacrum due to the weight of the body, but they must also counteract the tendency of the pelvis to rotate upon the sacrum. The bones of the leg push up on the pelvis at a point in front of the spine; their force tends to lift the front of the pelvis and rotate it. The pelvis is considered in its relation to childbirth in Chapter XX, and is shown in Figure 84.

Curves of the Spine.

The spine normally has four curves. In relation to the front of the body they are a convexity in the cervical region, a concavity in the

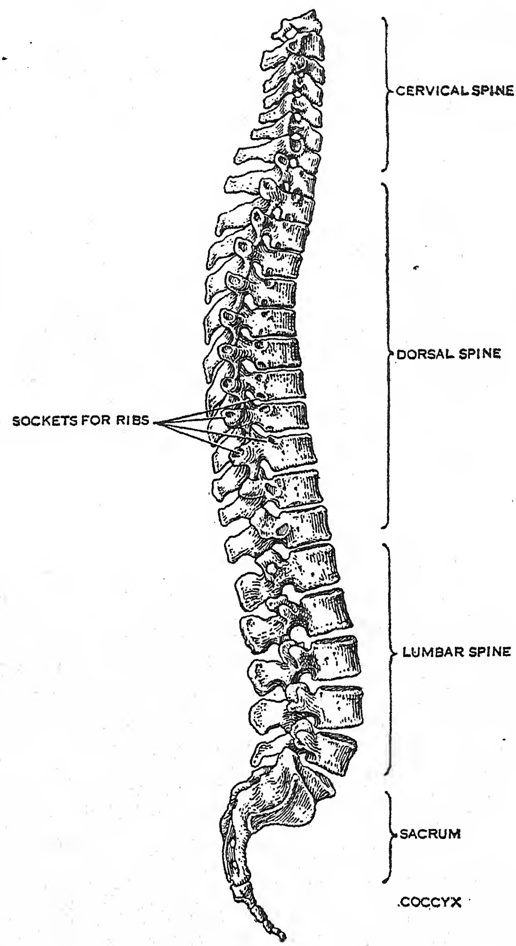


Figure 65. The Spine.

dorsal, a convexity in the lumbar, and a concavity in the sacral. The curves in the dorsal and pelvic regions are in comparatively rigid portions of the spine and are present at birth, but at this time the remainder of the spine is straight. The curvature in the neck appears only when the child begins to hold the head upright; the curve in the

lumbar region develops only when the upright position is assumed. These curvatures are thus secondary to position and tend to compensate for the inclination of the pelvis and the curvature of the dorsal region. It is these secondary curvatures which are at fault in improper

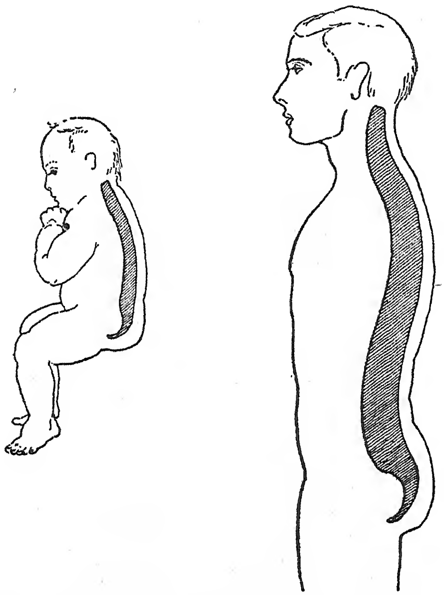
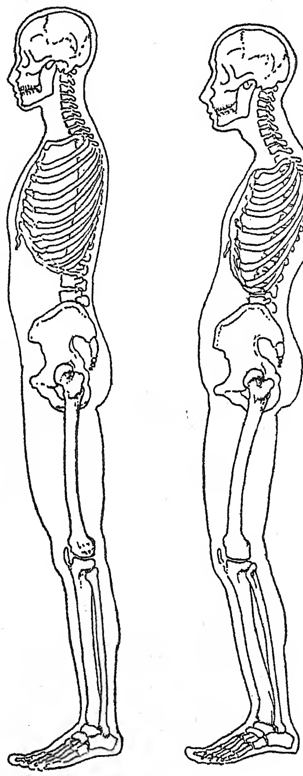


Figure 66. DEVELOPMENT OF THE SECONDARY CURVES OF THE SPINE.
The spine of the infant shows only the two primary curves; the spine of the adult shows, in addition, the secondary or compensating curves due to the erect posture.

posture; the primary or fixed curvatures are not then properly balanced, and a strain is put upon the ligaments and muscles of the spine. Excessive curvature of the lumbar region may displace abdominal viscera. Lateral curvature of the spine is known as scoliosis, a backward curvature of the dorsal portion of the spine as kyphosis, and an inward curvature of the lumbar portion as lordosis—swayback.

The balanced relations of the curves of the spine are so accurate that no one curve can be increased or decreased without a corresponding increase or decrease of the others. With every movement of the body the center of gravity shifts, and compensatory changes in the curvature of the spine must occur in order to maintain balance. In the proper standing or sitting position all the curves are slight, and

none of the spinal joints are used to their limit of motion. The load is evenly distributed to all of the supporting muscles, so that there is no excessive fatigue and the ligaments are protected from strain.



1 2

Figure 67. Position of Skeleton in Good and Bad Standing Postures.

(1) Good posture; line of gravity follows main line of bony structure, and bones carry the weight.

(2) Bad posture; a burden is thrown on the muscles and ligaments because of the exaggerated curves of the spine.

Incorrect Posture.

In incorrect posture the curvatures of the spine are exaggerated and the joints of the spine are used to the limit of their motion. The ligaments which normally check extreme ranges of motion are constantly under tension. Moreover, the muscles no longer carry an evenly divided burden. Those which are overworked become rapidly fatigued;

the burden placed upon the ligaments strains these structures. The skeleton possesses great resources for compensation to improper posture, so that this condition may be borne for a long time without

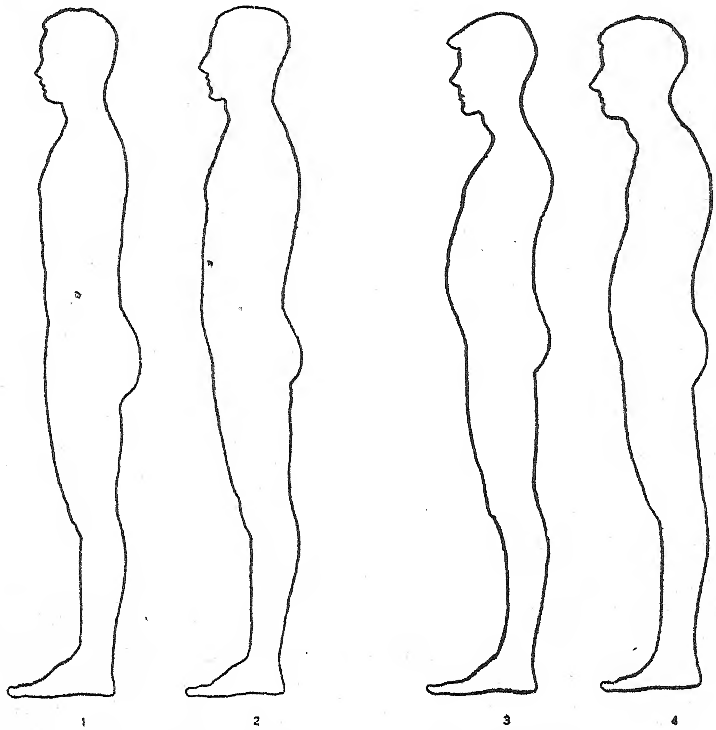


Figure 68. THE BODY IN GOOD AND BAD STANDING POSTURES.

(1) Best type of posture.
(2) Good posture but chest is not so well up and forward as in (1).
(3) Bad posture; head forward of chest, chest flat, abdomen relaxed, curves of back exaggerated.
(4) Very bad posture; head further forward than in (3) and abdomen more relaxed, curves of back exaggerated to extremes.

A large majority of men stand as in (3) or (4).

demonstrable damage. The ability to compensate varies with each individual, and seems to depend upon the difference in construction of the skeleton.

Figure 67-1 shows the normal skeleton in proper standing posture, and Figure 67-2 shows it in improper standing posture. In proper posture the line of gravity follows the main line of the vertical bony struc-

ture, and the bones carry more of the weight than in the second figure, where the burden is thrown upon the muscles and ligaments.

Figure 68 shows the body in silhouette in typical standing postures. It is in the postures shown as 3 and 4 that the ailments common to improper posture occur—backache, lumbago, legache, and disturbances in the digestive and urinary functions. It does not follow that incorrect posture is inevitably accompanied by symptoms. Violation of the principles of correct body mechanics predisposes to them; slight injury, extreme fatigue or illness may furnish the additional aggravating factor necessary to produce the acute effects.

The relationship between health and posture is two-sided: Ill health and fatigue cause improper posture; improper posture causes ill health and fatigue. It is possible to correct posture by working from two sides; the health must be improved and the proper body mechanics assisted. In working conditions the former means fresh air and good light, together with instruction in proper living. Development of normal body mechanics is assisted by prevention, so far as possible, of improper posture, by provision of suitable seating, and by arrangement of work so that it is not necessary for the worker to assume abnormal positions.

Principles of Correct Seating.

Many workers in stores, offices and factories spend nearly a third of the twenty-four hours in a chair. The shape of the chair contributes greatly to the maintenance of correct posture, and thus indirectly to the prevention of fatigue and development of proper bodily mechanics. Anyone can demonstrate to himself the point at which support is needed in the sitting position by sitting erect and then gradually relaxing, allowing the back to bend naturally. It will be found that the middle of the back bulges directly backward. Support for the back at this point is important in maintaining correct posture. This support is not furnished by the ordinary chair, which supplies a rest only for the shoulders. Moreover, for the back support to be effective, the seat of the chair must be narrow from front to back, approximately one foot. The shallow seat brings the occupant to the back of the chair, which should be bowed forward slightly to meet the small of the back. The chair should be of rigid construction in order to give support and steadiness. Adjustable chairs may at times be necessary for special work, but they are not otherwise advisable, for they are harmful when incorrectly adjusted and are often unsteady. The seat of the

chair should be solid. Cane bottoms are particularly undesirable, for they weaken rapidly and the worker is soon sitting on a wooden bar which crosses under the middle of the thighs. The seat should furnish support directly under the body.

The worker in an improperly designed seat tends to sit forward on the front part of the chair and use the back of the chair only during in-

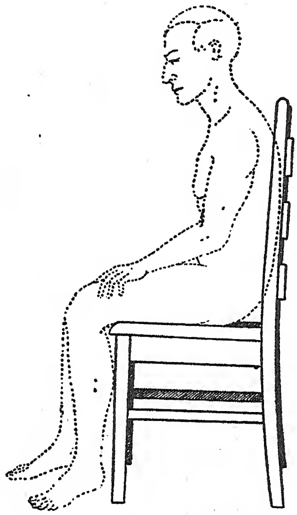


Figure 69. BAD SITTING POSTURE.
The chair does not give support to the lower part of the back.

tervals of rest from the fatigue produced by sitting with no support to the back.

In occupations of a nature which make back support impossible, it is at times advantageous to tilt the seat of the stool or bench so that the front is slightly higher than the rear. This has a tendency to throw the shoulders back and to counteract the bowing of the back.

The height of the chair should be such as to allow the worker's feet to rest firmly upon the ground, neither raised at the heel nor thrown sideways or in front to meet the floor. Each length of leg requires its own height of chair. By arranging the work on the table or bench so that a minimum of motion is required, efficiency as well as relief from strain and fatigue is achieved. The arrangement of material and of machinery is particularly important for avoidance of cramped or strained positions. A worker at a sewing machine who keeps scissors

or other implements in her lap by supporting one leg on the machine is in a cramped and strained position which leads to fatigue and to pains in muscles and ligaments. Likewise an operator who is forced to watch his work with his head thrown to one side, as in avoiding glare from improper lighting or because of obstructed vision due to poor arrangement of the machinery, is contributing greatly to his fatigue, and also to the far-reaching effects of poor body mechanics.

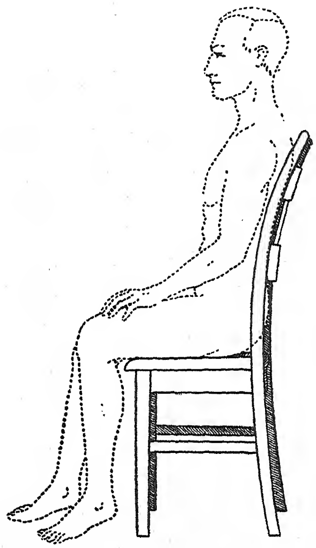


Figure 70. GOOD SITTING POSTURE.
Chair with shallow seat and support for lower part of back.

Mechanism of Human Locomotion.

In walking, the body is leaned forward until a line perpendicular to the earth and passing through the center of gravity is brought in front of the base formed by the feet. Equilibrium is thus disturbed and if unchecked the body would fall. The equilibrium is restored by swinging forward one leg and supplying a base of support with the foot of that leg. During the instant that equilibrium is restored the body is supported on both feet; during the remainder of the pace it is supported on only one foot. To effect the next pace the foot in the rear is "unrolled" on the ground from heel to toe, rises on its toe, and with a thrust shoves the body forward to bring the center of gravity in front of the foot resting upon the ground. The foot which has furnished the

propulsion then swings to the front to restore equilibrium. The regular repetition of this sequence constitutes the act of walking.

The movements of walking are complicated by oscillatory movements of parts of the body other than the legs. The feet exert a lateral pressure as well as a vertical pressure, and the body is thrown from side to side with each pace and at the same time partially rotated at the hips. The oscillation of the trunk is compensated by a swinging motion of the arms; as the right leg advances, the left arm swings forward, and as the left leg advances, the right arm is swung.

The swinging of the leg forward to restore the equilibrium of the body in walking is not accomplished alone by the pendulum-like action of the free limb. The period of the leg as a pendulum is too slow to swing forward under its weight alone; instead its forward movement is accelerated by the pull of the muscles. Unlike most other animals—the horse, for example—the human leg has a mass of muscle, the calf, relatively near to its extremity. This mass adds inertia to the movements of the legs—that is, increases its radius of gyration.

The act of running is essentially of the same character as walking, with the difference that the period of double support with both feet on the ground simultaneously is missing. The legs alternate in single support of the body, but between the instants of support there is a time in each step when the body is completely off the ground.

Foot Strain.

The foot is so constructed as to afford two series of elastic arches. One series extends longitudinally, running from the heel to the ball of the foot; the other arch is lateral, extending from side to side across the ball of the foot. These arches are formed by a series of bones united by ligaments and held in position by muscles. If the muscles are weak the arches tend to collapse, stretching the ligaments and causing foot strain and flat feet. The custom of wearing shoes from infancy onward, and often ill-fitting shoes, predisposes to weakness of the foot muscles. The immediate causes of foot strain are muscular weakness as in convalescence from long illness, excessive weight of the body, and excessive use of the feet, particularly in standing on hard floors.

The shapes of the arches found in the feet of different individuals vary; some are high and some are low. The extent to which the arch is strained or collapsed cannot therefore be judged accurately by looking at the arch; there may be strain with normal-appearing arches, and

none with those that appear low. The symptoms that develop from foot strain are usually pain in the arch of the foot and, with prolonged standing, pain in the calf of the leg. The feet may become swollen and hot; they often perspire excessively. Sometimes to obtain relief the feet are turned outward in walking. The proper treatment of foot strain requires the services of an orthopedic physician.

Calluses on the ball of the feet and pain in this region are a common complaint especially among individuals who have high arches and particularly so among women who wear high-heeled shoes with short vamps. High heels, aside from predisposing to this condition, which may be followed by deformity of the toes, also tend to shorten the Achilles tendon or heel cord. Attempts to wear low-heeled shoes as in sports are then followed by pain in the foot and calf of the leg. Short heel cord may also occur without known cause. Low-heeled shoes are then uncomfortable; the individual affected tends to turn the feet outward and walk on the sides of them. This condition predisposes to flat feet.

Clubfoot is a deformity appearing at birth; usually the foot is turned inward and backward so that the individual affected walks on what should normally be the outer side of the foot. The abnormality, if uncorrected, tends to increase with age; hence a moderate clubfoot in childhood may develop into severe deformity by the time adolescence is reached. Clubfoot can be corrected without difficulty and usually without surgical operation in an infant; after infancy the correction becomes progressively more difficult with each year the condition is allowed to persist.

CHAPTER XVII

MUSCULAR ACTIVITY AND FATIGUE

THERE ARE IN THE BODY THREE TYPES OF MUSCULAR TISSUE: THE SO-CALLED involuntary or smooth muscle of the visceral organs, such as the intestines and bladder; the heart muscle; and the striated or skeletal muscle through which voluntary movements are performed. The fundamental character of muscular action is the same for all three types. They resemble one another in general appearance, but they are distinguished by microscopic differences in structure and by the character of their contraction. Smooth or involuntary muscle contracts slowly, and its contraction may be maintained for a long time without fatigue. Voluntary muscle contracts rapidly, but it also becomes fatigued rapidly. Heart muscle is intermediate in character between the other two types, but it has in addition the property of developing its own stimulus for rhythmic contraction. The discussion below applies particularly to voluntary muscle.

Structure of a Muscle.

A muscle, the biceps for example, is composed of many thousands of muscle fibers placed parallel and bound together by connective tissue; the whole bundle is surrounded by a sheath of connective tissue. The muscle fiber is the unit of muscle structure, and is, in fact, a replica of the entire muscle. A muscle fiber is a cylindrical thread with a diameter varying between 0.1 and 0.01 millimeter and with a length not exceeding 36 millimeters (1.44 inches). It consists of an elongated spindle of semi-gelatinous muscular tissue. This muscular tissue has a fine structure showing both longitudinal and cross striations, which are marked out by alternate areas more or less dense in the viscous tissue. Each muscle fiber is surrounded by a sheath of connective tissue. This sheath extends beyond the muscular tissue to form a minute cord for each fiber. The muscle is formed by rows of these minute muscle fibers with their terminal extensions of connective tissue joined together. The extensions of these combined cords of connective tissue

at each end of the muscle form the tendons of the muscle. The tendons are attached to the bones upon which the muscle exerts its traction.

Arrangement of Antagonistic Muscles.

A nerve fiber runs to each of the muscle fibers. When impulses pass down these nerve fibers the muscle contracts as a whole; when the impulses cease the muscle relaxes. A muscle performs its work only in

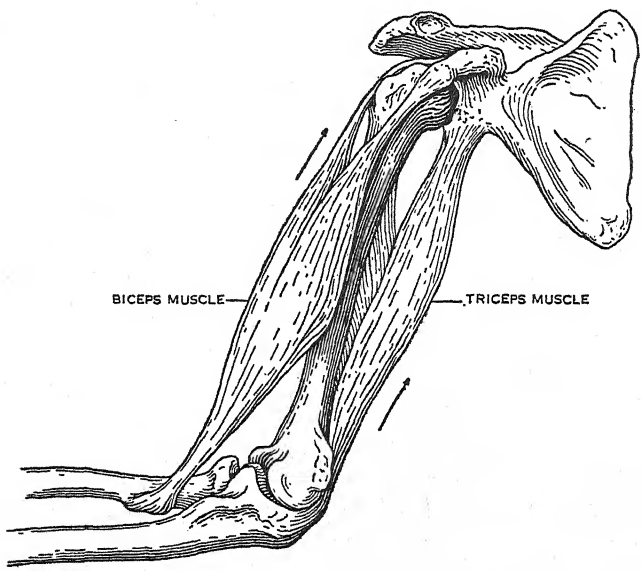


Figure 71. Biceps and Triceps Muscles as Antagonists in Moving the Forearm.

the direction in which it contracts; the relaxation is entirely passive. Before further work can be performed the muscle must be elongated. This elongation is accomplished through the arrangement of antagonistic muscles. Thus the biceps muscle on the front of the upper arm by contracting pulls up or flexes the forearm; the triceps muscle on the back of the arm acts to extend the forearm to its original position, thus enabling the biceps to contract once more. This arrangement of muscles in antagonistic pairs also allows the various parts of the body to be held rigid. When the biceps and triceps are contracted simultaneously the forearm is held rigid. A similar action in the muscles on both sides of the spine maintains the body in the erect position.

Mechanics of Muscular Contractions.

When a muscle is stimulated by a nervous impulse it undergoes a change of state resulting in contraction. The muscle passes temporarily into a new elastic condition and develops new potential energy, so that it exerts a pull upon the structures to which it is attached. If the pull of the muscle is sufficient to overcome the resistance, it shortens, its potential energy is converted into kinetic energy, and mechanical work is done. In contracting, the muscle does not change its volume; it merely changes its shape, becoming shorter and thicker. To effect the contraction the muscle fibers do not pull upon the connective tissue sheaths which surround them; instead, the viscous muscular tissue which fills the sheaths tends to become more spherical in shape. In doing so it exerts a lateral force. This lateral force tends to widen the sheaths and to shorten them. The resultant of all these forces is a pull exerted through the sheaths and transmitted to the tendons at the ends of the muscle.

The lateral forces of the muscular tissue have their greatest longitudinal resultant when the muscle fibers are stretched out to their full length. Correspondingly, as the fibers become more spherical the longitudinal resultant of the forces diminishes; if the fibers were to become completely spherical, the forces would be exerted equally in all directions and no pull would result. As the action of the muscle is the sum of the actions of all of its fibers, the muscle also has its greatest pulling force when it is stretched out to the greatest extent; as the muscle shortens this pulling force is diminished.

The pulling force of a muscle, when measured as external work, is modified by the mechanical advantage of the lever system through which it is transmitted, a fact that may be illustrated by the action of the biceps muscle. This muscle is attached by one end to the shoulder, and by the other end to the bones of the forearm a short distance below the elbow. When the muscle contracts it flexes the forearm. When the forearm is fully extended the biceps pulls at a great mechanical disadvantage, for only a small fraction of its force is used in flexing the forearm, and a much larger component is uselessly expended because of the direction at which the bones are placed. As the arm rises the biceps pulls to better mechanical advantage, and a greater proportion of its force is in the direction of flexing the forearm. When the arm is fully extended the biceps is stretched to its greatest length and has its maximum pulling force; as the arm rises the biceps shortens and its pulling force is diminished. The diminished pull of the biceps is com-

pensated by the rising mechanical advantage of the lever system to which it is applied. As a result the lifting power at the hand is nearly the same from full extension of the forearm to half flexion. Beyond the point of half flexion, both the pull of the biceps and the mechanical advantage of the lever system diminish, so that the lifting power falls off rapidly.

The fact that the mechanical advantage of the lever system through which the power of the muscles is transmitted, varies with position is of great importance in planning industrial occupations. It is also a neglected feature. The position of a seat in relation to a foot treadle or tools that must be reached from a bench or rack should be planned for the most advantageous movements. This principle should be applied also in planning the activities of the worker who stands or walks in performing his work. Often advantageous posture is more important in preventing fatigue and strain than is the elimination of unnecessary motions, a feature emphasized in industry. In athletics the posture in relation to the task to be performed has been highly developed; the so-called "form" in this field is essentially the posture and motion that afford the most advantageous transmission of the power of the muscles.

Chemical Changes in a Muscle During Contraction and Recovery.

The chemical changes occurring in a muscle during contraction and relaxation are highly complicated and not yet fully established in all details. The present conception is that there is in the muscle a substance called phosphocreatine which contains phosphorus and a substance called creatine which in chemical structure somewhat resembles an amino acid. When the muscle is stimulated to contract, phosphocreatine breaks down into phosphoric acid and creatine; the energy liberated in this reaction is applied to the pull of the muscle. During relaxation the phosphoric acid and creatine are reunited to restore the phosphocreatine in preparation for further contractions. The restoration of the phosphocreatine requires the same amount of energy that it liberated in breaking down into phosphoric acid and creatine. This energy is supplied by converting glycogen into lactic acid. The glycogen is obtained from sugar in the blood. As a final step in the recovery process one-fifth of the lactic acid thus formed is burned. Oxygen taken from the blood is used for this combustion and carbon dioxide is liberated and absorbed into the blood. The energy from the combustion of lactic acid converts the remaining four-fifths of the

acid back into glycogen which can then be used as fuel for further muscular contraction. Although the energy for muscular contraction comes ultimately from glycogen, the involved and indirect processes by which the energy is converted into a muscular pull have an advantage. The advantage is that of immediate action which is highly desirable for quick movement. The breaking down of the phosphocreatine, which releases the culminated energy for the contraction, requires no oxygen; it occurs instantaneously when the stimulating nervous impulse reaches the muscle.

Heat is liberated by the chemical changes within the muscle, some when the phosphocreatine breaks down but much more during the oxidation of the lactic acid that is formed. Thus in a brief muscular contraction most of the heat develops during the period of relaxation. The blood which supplies the oxygen to the muscle and takes away carbon dioxide also removes the heat developed during the chemical changes. Although the breaking down of the phosphocreatine requires no oxygen, its reformation does. Therefore, if oxygen is not supplied by the blood the phosphocreatine is soon exhausted, the muscles fail to recover and become incapable of further action. The limiting factor in maintained vigorous exertion is the rate at which oxygen can be supplied to the tissues, and this depends upon the circulation; the heart thus becomes a limiting factor to muscular exertion.

The breaking down of phosphocreatine can, as stated, proceed for a short time without oxygen; a certain amount of oxidation may thus be put off to a time after the exertion is ended. This delayed oxidation occurs during the recovery process; the continued heavy breathing after the exertion and the slow return of the heart to the normal rate are indications of this process. During exertion the tissues run into debt for oxygen, but the extent to which they can do so is limited. Even in the most favorable cases the body becomes incapable of further exertion when an oxygen debt of about fifteen liters has been incurred. The maximum rate at which oxygen can be supplied to the body by the circulation depends upon the development and physical state of the individual, but the maximum for the best-developed men in the prime of condition is probably not much more than four liters a minute; it is much less for most men. If the exertion is at a sufficiently moderate rate to require less than the maximum of oxygen which can be supplied by the blood, the exertion can be maintained for a comparatively long time before the muscles become fatigued. If the exertion requires more oxygen than can be supplied to them, the exertion is limited by

the increasing oxygen debt; when the full debt is incurred, the exertion ceases. The fact that an oxygen debt can be incurred makes it possible for the body to perform extremely violent muscular exertions for a short time.

In describing the chemical changes occurring during muscular contraction it has been assumed here that glycogen, hence sugar, is the sole fuel of muscular exertion. This is not strictly the case. Sugar furnishes the most efficient fuel (see page 73), but fat may also be utilized although not without some sugar.

In Chapter IV static effect and also muscle tonus and the fallacious distinction drawn between rest and exercise, are discussed. These matters are pertinent to the subject dealt with here.

Optimum Speed and Internal Work.

Muscular tissue is a viscous material; it offers resistance to change of shape during contraction, and energy is expended in overcoming this internal resistance. If the muscle contracts slowly the energy thus expended is slight, but the internal resistance increases with the speed of contraction and at a more than proportional rate. At the maximum speed at which the muscle can be made to contract, all of its available energy is used in overcoming the internal resistance and none is left to perform work. When the muscle does external work, as in lifting an object, the speed of contraction is retarded by the load. For each amount of load upon the muscle there is a speed at which the work can be performed most efficiently. High speed is wasteful, for if the speed is forced beyond the optimum for the load, the increasing internal resistance consumes energy and fatigue develops rapidly. Sustained activity can be performed only at or below the optimum speed. Figure 72 shows the amount of oxygen required in relation to the speed of performance during stationary running and running. The oxygen requirement expresses the energy expended by the muscles in performing the exercise; but it does not exactly correspond to the oxygen consumed during the time of the work, for, as will be seen later, the body may develop a deficit of oxygen which is made up after the work is completed. At 60 steps a minute the oxygen requirement was 0.5 liter a minute. On doubling the rate, 120 steps a minute, the oxygen requirement was also doubled; the speed had not yet become sufficient to require a large proportion of the energy in overcoming the resistance of the viscous muscular tissue. When the speed was increased to 180 steps a minute the oxygen requirement rose to 4 liters, or eight times

that of the initial speed. An increase to 240 steps a minute brought the oxygen requirement to 8 liters, while at a rate of 280 steps a minute the oxygen requirement rose to 24 liters, an exertion that could be maintained for less than a minute.

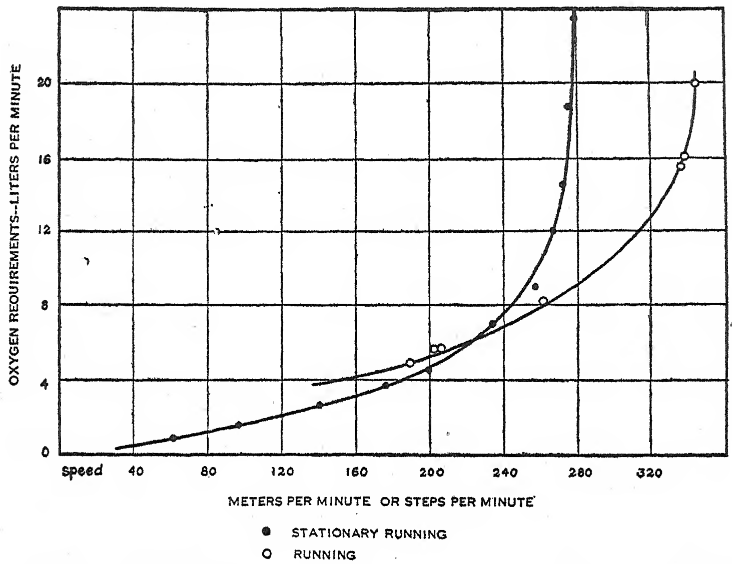


Figure 72. Oxygen Requirement in Relation to Speed of Performance. The oxygen requirement (oxygen consumption plus oxygen debt) is shown for various rates of activity. As the speed of performance increases, the oxygen requirement also increases but at a more than proportionate rate. (After A. V. Hill.)

Other Factors Determining Speed.

The resistance of the viscous muscular tissue is one of the main factors in determining the efficient rate for work, but other factors also play a part. One of these factors is the mechanics of the part of the body used. The natural period, or rate of swing, of the arm or leg as a pendulum plays a part in establishing the optimum speed of operation. In some cases, such as in pounding with a sledge hammer or in rowing, the rate of work is influenced by the rate of breathing; a racing crew pulls raggedly when the rate of stroke is too slow to permit sufficiently rapid breathing, while a high rate, forty-five or more strokes a minute, cannot be maintained for long because breathing becomes too shallow to be effective.

A part of the strain of work is mental; some of this mental factor is

removed in acts which are rhythmically repeated, for after practice the art becomes a timed reflex. The timing of the act by some outside influence, such as the music in dancing, the pace-maker in running, or the coxswain of a crew, further removes the necessity for mental strain, for the outside factor then supplies the stimulus at the proper time,

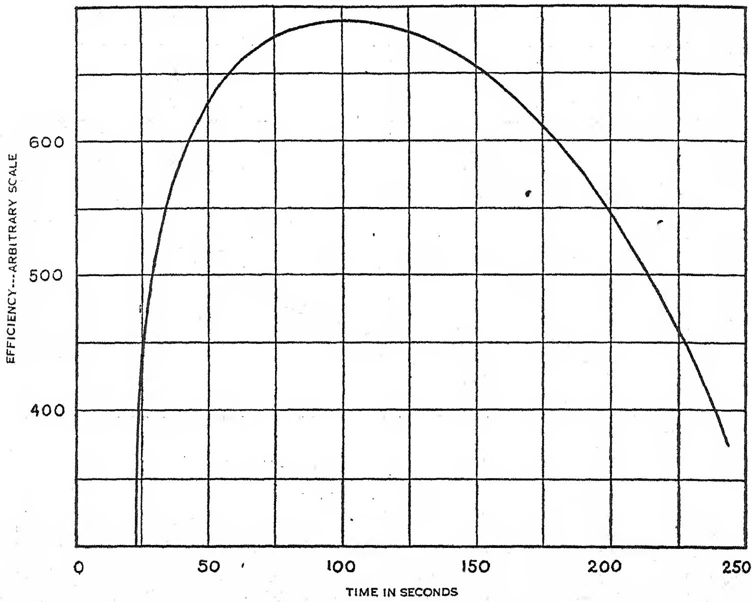


Figure 73. Muscular Efficiency and Its Optimum as Illustrated in Climbing Stairs at Different Speeds.

The efficiency recorded is the inverse of the oxygen requirement for the effort. The efficiency is diminished by both fast and slow rates of climbing, thus indicating that there is an optimum rate for the effort. (After A. V. Hill.)

and the act follows almost unconsciously. The establishment of rate by sensory impressions from some rhythmic source outside of the body is seen particularly in men marching to the music of drums. If the work performed is not rhythmic in character the outside influence then becomes a disturbing factor; music hinders rather than helps a worker using a typewriter or a telegrapher sending messages.

Influence of Muscular Activity upon Other Bodily Functions.

Muscular activity influences the function of all parts of the body. The consumption of oxygen by the body varies in proportion to the

rate of muscular activity, and the amount of air breathed varies in a corresponding degree. The response made by breathing to an increased rate of muscular activity is not instantaneous; from one to two minutes is required for the establishment of the new volume of breathing. Likewise when the exertion is stopped, breathing does not fall immediately to the resting level, but returns only gradually. The circulation is altered by exertion; the arteries supplying the muscles dilate, thus allowing a greater flow of blood to them. This dilation is in part compensated by the constriction of arteries in other parts of the body, particularly in the abdominal organs, and by an increased pumping action of the heart (see Chapter VI), as is evident in the increased pulse for a time after the exertion. The heat produced in the exercising muscles raises their temperature slightly; if the exertion is vigorous the temperature of the whole body rises. Dissipation of the increased amount of heat involves a dilation of the blood vessels in the skin, and a greater activity of the sweat glands. During muscular exertion the glycogen in the liver is mobilized in order that the greater utilization of sugar by the muscles may be compensated. After exertion the metabolism of the body is elevated, and even in the resting state remains above the basal rate for many hours.

Influence of Bodily Condition upon Muscular Activity.

All the functions of the body are influenced by muscular activity and participate in the activity. The cooperation of these functions is essential for the performance of the activity. When any one function is limited, muscular activity is correspondingly limited. The heart is the main organ determining the extent to which muscular activity can be sustained. The effects of athletic training, aside from the development of skill, are largely concerned with the conditioning of the heart. The main factor is the control of its rate, so that it will not become excessively fast and thus cut down the flow of blood by incompletely filling between beats. A well-trained athlete performing work which does not carry him to exhaustion has a pulse rate running up to but rarely exceeding 140 to 170 beats a minute. Under the same exertion a man in poor physical condition has a pulse of 190 or even higher, but the volume of blood which his heart pumps is less than that of the trained man, even though their hearts may be of the same size. Tobacco and coffee, if used in excess, increase the rate at which the heart beats; thus these substances diminish a man's "wind"—that is, make him short of breath on exertion. Shortness of breath is due to a failure of

the circulation of blood to keep pace with the exertion, and not to any inability of the lungs or muscles involved in breathing. A man with valvular disease of the heart becomes short of breath on slight exertion, or even while at rest, not because his muscles or his lungs are deficient, but because his heart does not pump the normal amount of blood; consequently the amount of oxygen reaching his tissues is less than normal.

Lack of cooling power in the air, as determined by its temperature, its movement and its humidity, diminishes or limits muscular exertion and also the incentive to exertion. This topic will be discussed at length in Chapters XVIII and XIX. A similar limitation may result from the inhalation of carbon monoxide from the exhaust gas of internal-combustion engines or from other sources. The influence of organs, even those as remotely connected with muscular exertion as the pancreas and thyroid gland, is nevertheless profound upon physical vigor. A man with myxedema lacks inclination for muscular exertion; a man with exophthalmic goiter has the incentive in high degree, but is too easily fatigued to do work; the man with serious diabetes is too weak.

As the nervous system controls the muscles and all the correlated functions of the body, its condition influences muscular exertion. This influence may be shown in variations in the action exercised by the cerebrum upon the reflexes. During excitement or other strong emotions, exceptional muscular exertions may be performed.

The nervous influence upon muscular exertion is not limited to the emotional states, but is varied by any factor which disturbs the normal balance of the nervous system. Absorption of the products of infection, disturbance of the glands of internal secretion, and poisons such as carbon monoxide, or alcohol and other hydrocarbons, all influence the nervous system. Even slight infections diminish muscular activity and predispose to fatigue.

The Maximum of Human Power.

The maximum power that can be developed during an exercise involving the use of a large number of muscles varies with the length of time over which the task is extended. A healthy man with well-developed muscles, working very hard, can for eight or ten hours sustain an average production of 0.1 horsepower. It has been found by dietary studies on men doing heavy work, such as lumbermen, that the total daily expenditures may reach a value as high as 6000 kilo-

calories. Of this total at least 4000 are expended during a ten-hour working day. Of these 4000 kilocalories not more than 800 are expended as work, the remainder being dissipated as heat. Eight hundred kilocalories in ten hours is equivalent to work at the rate of 0.1 horsepower. The same man attempting to do work at the rate of 0.2 horsepower could not sustain it for more than two or three hours without becoming exhausted. In rowing in racing shells trained athletes do work up to 0.5 or 0.6 of a horsepower during a race of twenty minutes. A man can, for ten or fifteen seconds, develop as much as 3 to 3.5 horsepower, as in a hundred-yard dash.

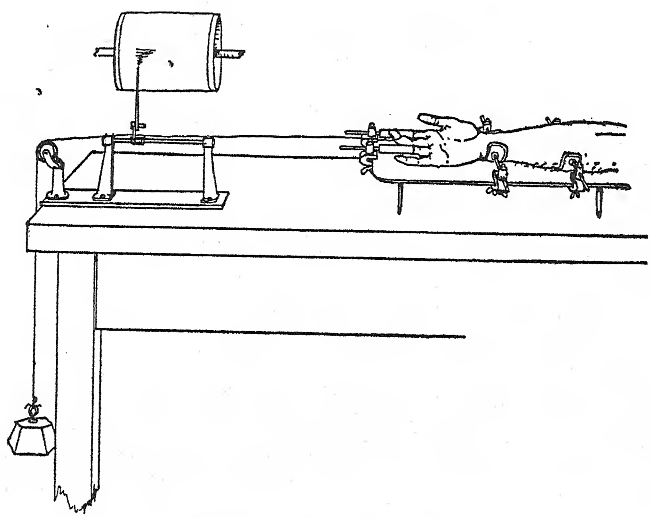


Figure 74. FINGER ERGOGRAPH.

Apparatus for recording the work done by the finger in repeatedly lifting a weight. The stylus attached to the cord carrying the weight writes upon the paper covering the revolving drum. Typical records are shown in Figure 75.

Fatigue.

The word fatigue is often used incorrectly to denote incapacity or disinclination for work arising from any cause; correctly, fatigue means diminished capacity for work as the result of doing work. The classical picture of the fatiguing muscle is afforded by a finger ergometer. In using this apparatus the hand rests on its back on a table; a cord extending over a pulley and bearing at its end a weight is attached to the index finger. Each time the finger is bent it lifts the weight. The contractions are recorded by a pointer attached to the weight and

writing on the surface of a strip of smoked paper on a rotating drum. The type of record thus obtained is shown in Fig. 75-1. The contractions of the muscle are indicated as vertical lines, and in this record occur at intervals of one a second. The first few contractions increase progressively in height. This indicates an increase in the force and extent of the contraction of the muscle, and is due to the muscle "warming up." Following this ascending portion, the contractions are for a time approximately of uniform height. A gradual decline in height then follows; this decline indicates the development of fatigue. The muscle

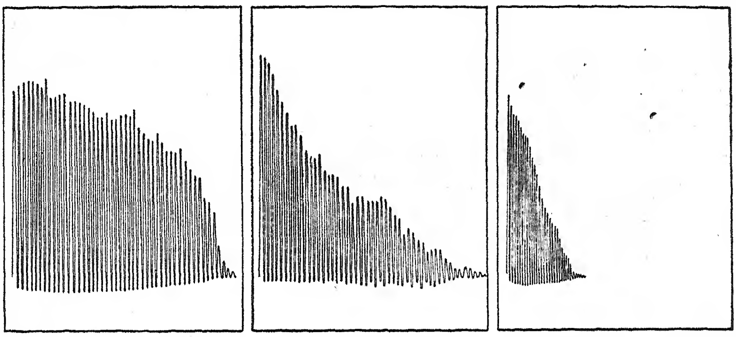


Figure 75. Tracings from Ergograph.

(1) Finger lifting weight at the rate of 60 times a minute. The diminishing amplitude of the movement shows the development of fatigue.
(2) Continuation of tracing (1) made after a short rest, showing only partial recovery from the fatigue of the previous work.
(3) Finger lifting the weight at the rate of 120 times a minute, showing the rapid development of fatigue at the increased rate of movement.

is then allowed to rest for a short time, and the action then resumed; the contractions, Figure 75-2, now are equal in height to those in the middle of the previous record. That the rest has not been of sufficient duration to allow complete recovery is indicated by the fact that in the second series of contractions fatigue develops more rapidly than in the first. Figure 75-3 represents a record in which the finger contracted at twice the rate used in making the previous records. In this case fatigue develops in much less than half the time of the first record.

The muscle performing the work in these experiments becomes fatigued because the reparative processes occurring within the muscle, i.e., the restoration of phosphocreatine by the conversion of glycogen to lactic acid and the subsequent combustion of the lactic acid, could not keep pace with the demand made for the liberation of energy by the

breaking down of phosphocreatine. Rest was finally forced by the inability of the muscle to contract. During rest an opportunity was given for the restoration process to occur. The muscle was then able to resume the contractions. The rate at which fatigue developed depended upon the extent to which the destructive processes were in excess of the restorative processes; see 1 and 3, Figure 75. The extent of recovery after rest depended upon the completeness of the restorative processes; see 1 and 2, Figure 75. The development of fatigue as illustrated from the activity of the finger occurs in any exercising muscle when the rate of exertion is forced beyond the muscle's capacity for sustained exertion. The rate of blood flow to the exercised muscle is an important feature in determining the rate at which fatigue develops. If for any reason the blood supply is diminished the development of fatigue is hastened. Such is the case in the intermittent claudication occurring as a result of sclerosis of the arteries in the legs (see page 154).

Fatigue is not determined by the increase in total energy expenditure of the body resulting from the exercised muscles. The amount of energy expended by the muscles of the finger as described here was small as compared to that of the body as a whole even when at rest, but it was large for the small group of muscles involved. The fatigue of violent athletic exertion or strenuous work develops in large groups of muscles in the same manner that it develops in the exercised finger; but, because of the greater energy expenditure of the larger masses of muscle, other signs of fatigue develop. These involve respiration, circulation and heat dissipation; breathing is violent and labored, the heart beats rapidly and the skin becomes red and moist with sweat. These changes indicate merely an increase in total energy expenditure and not any difference in the fundamental process occurring in the muscle of a small group or a large group when exercised. The capacity of the heart to pump blood imposes a limitation on exertion only when large groups of muscles are brought into play. When the heart is diseased, this limitation becomes correspondingly greater; breathlessness then follows slight increase of total energy expenditure.

Fatigue, as described here, occurs only from the overexertion of a muscle; it is relieved by rest. In industrial procedures true fatigue is unusual. Nevertheless, the term is often applied to tiredness, disinclination for work, and diminished production developing during the course of the working day. In such cases the "fatigue" so-called is due to causes other than the accumulation of end products in muscles that have been exercised. Ordinarily rest alone does not relieve this sort of

tiredness, although it is a common practice to give short rest periods in the course of the working day. The tiredness here may be due to many factors; some are physiological, but many are psychological.

A decrease in the sugar of the blood may be accompanied by a feeling of tiredness; if severe it may lead to incapacity for work. Thus in long-sustained vigorous exertion, such as that of the Marathon runner, collapse occurs when the runner has utilized all the available store of carbohydrate in his body, but he may resume his exertions after he has been fed sugar. Sugar depletion rarely develops to its full extent in ordinary occupations, and yet in a lesser degree it plays a part in the tiredness that develops during the working day. The immediate fuel for muscular activity is carbohydrates; on a diet of fat the muscles act less efficiently and more heat results from the same amount of external work. After meals containing carbohydrate a greater proportion of this material is burned in the muscle, and less fat, so that work is performed with less effort. Some hours after the meal the supply of carbohydrate stored in the body is diminished and more fat is utilized. The efficiency of the working muscles diminishes and more effort is required to do the work. At this time the taking of carbohydrate-containing foods helps to relieve the tiredness. It would be wiser in industrial procedures, and in homes and schools as well, to give feeding periods rather than only rest periods (see page 122). It must be borne in mind, however, that the food taken in such between-meal feedings is a part of the total daily diet; less is eaten at the "regular" meals. The choice of foods for the between-meal feedings must be such as to fit them into the complete normal diet (see Chapter V).

Ill health, undernourishment, eye strain from inadequate lighting are contributing factors to the development of tiredness. So also are discouragement and the numerous social and sociological maladjustments that occur in the home, office, store and factory. Often in industry the diminished production attributed to "fatigue" has its real cause in the disadvantageous conditions under which the work is done and not in the exertion of doing the work.

CHAPTER XVIII

TEMPERATURE OF THE BODY AND ITS REGULATION

THE FOODSTUFFS, AFTER BEING STORED OR BUILT UP INTO THE TISSUES OF the body, are burned, and the energy is liberated as work and heat. This combustion, which is the very essence of life, is a chemical reaction. The rate at which chemical reactions occur, their velocity, is influenced by the temperature; at low temperatures they proceed slowly, at high more intensely. The reactions in the body also obey this rule. If the temperature of the body is lowered, all of its functions are depressed; the rate at which impulses are transmitted in nerves decreases, the heart beats more slowly, and the mental activity diminishes. As it is raised, all such functions are hastened, but at a temperature only a few degrees higher than that normal to the human body; tissues, especially the nerves and brain, are injured.

The so-called "cold-blooded" animals do not regulate the temperature of their bodies and are subject to the temperature of their surroundings. The frog is motionless on cold days and active only on warm days. During the winter months this animal goes down into the mud a little below the frost line; its vital combustion is depressed by the temperature to such a degree that it is able to live through the winter on a small store of food in its tissues.

Animals which maintain the temperature of their bodies constant can carry on a high degree of activity independently of their surrounding temperatures. The so-called "warm-blooded animals" are birds, and most mammals, including man. A few mammals, such as bears and other hibernating animals, are warm-blooded for part of the year; but during the time of their winter sleep their body temperature falls and with it the energy expenditure and the need for food.

Temperature of the Body.

The temperature of all warm-blooded animals is nearly constant in each, but in different species ranges from 37° to 43° C. (98.5° to 110° F.), with the temperature of man near the lesser figure and that of birds at the greater. The temperature recorded varies to some extent with the part of the body from which it is taken. With the thermome-

ter placed in the rectum or in the stream of urine, the temperature is approximately 1° F. higher than the temperature of the mouth. The higher values represent more nearly the real temperature of the internal structures of the body than does the temperature of the mouth. The temperature of the skin varies greatly, for it is through the skin that the heat dissipation is regulated.

There is a slight individual variation in the temperature of normal men; furthermore, the temperature of each individual varies daily through a range of 1° to 2° F. This diurnal variation runs a regular course; body temperature is at its minimum between three and five o'clock in the morning, and at its maximum between three and five o'clock in the afternoon.

Source and Distribution of Heat.

The heat which maintains the body at its normal temperature is derived largely from the contraction of the muscles, and to a less extent from the metabolic activities of the liver and other glands. The heart and those muscles which carry out the movements of respiration are active even when the other muscles are relaxed. But even the resting muscles produce some heat, for the relaxation is never complete. The slight pull of tonus, which distinguishes the living muscle from the dead, involves a continual slight oxidation and a corresponding production of heat. The basal metabolism, as discussed in Chapter IV, represents this minimum production of heat, which for all normal persons is about 39 kilocalories per hour for each square meter of body surface. From this level the heat production may rise ten-, or even fifteen-fold in vigorous muscular exertion.

The circulating blood serves to distribute the heat throughout the body and thus to keep the temperature of all parts nearly uniform. The temperature of an exercising muscle rises above the temperature of the rest of the body; but the rise is slight, for the blood flowing through the muscle is heated to the same temperature and on flowing to other parts of the body distributes the heat to areas which are less warm. Blood after passing through the skin returns to the heart at a lower temperature.

Regulation of Body Temperature.

Warm-blooded animals are properly called animals of uniform temperature, for they maintain within narrow limits a constant body

temperature. They do so by means of two forms of regulation—physical regulation and chemical regulation. Physical regulation is the control of the heat loss from the surface of the body. It is effected by the adjustment of the flow of blood through the skin and by the evaporation of sweat from the surface. When the flow of blood through the skin and the secretion of sweat are reduced to their lowest possible amounts, the heat loss through the skin is at its minimum. If the surrounding temperature is so low that the resting heat production of the body is insufficient to maintain the normal temperature, chemical regulation is called into play. It acts as a form of enforced exercise. The metabolism is increased by voluntary contractions of the muscles in stretching the arms, yawning and stamping, and finally by shivering. Chemical regulation can be aided by the increase in metabolism which results from taking food, particularly protein; but ordinarily chemical regulation is the less frequently employed of the two modes of controlling the temperature of the body, for we limit the loss of heat from the skin by means of clothing and by heating the air artificially.

Physical Regulation of Temperature.

Eighty per cent or more of the elimination of heat from the body occurs from the skin. The loss of heat from this surface is not due to direct conduction of heat from the underlying tissues and organs of the body. Beneath the skin is a layer of fat which insulates the body and diminishes the conduction of heat from the tissues to the overlying skin. The skin may attain a low temperature while the tissues a half inch beneath it are at the normal body temperature, although in the legs and arms during exposure to cold the internal temperature may fall considerably. The greater part of the heat eliminated from the skin is brought to it by the circulating blood.

The proportions of the total heat dissipated through various channels are given in Table XII. The figures are only approximate and apply to an individual of moderate activity (2800 calories) in comfortably warm surroundings.

Table XII

1. By food and water and excreta	2.0%	or	56	Calories
2. By expired air	11.5%	"	322	"
3. By evaporation from the skin	14.5%	"	406	"
4. By radiation and conduction from the skin	72.0%	"	2016	"
	100.0%	"	2800	"

Automatic Operation of the Physical Regulation.

The skin is heated by the blood flowing through it; the rate of heat loss by conduction and radiation to the air is determined by the difference between the temperature which is thus produced in the skin and that of the surrounding air. The amount of heat lost through the evaporation of sweat is determined by the rate of secretion of this fluid and by the capacity of the air to take up moisture as vapor. Sweat wiped off in liquid form does not assist in cooling the body.

The size of the blood vessels in the skin and the activity of the sweat glands are regulated by impulses reaching them through nerves. These nerves are influenced by two controlling factors; (1) a center of control in the mid-brain, and (2) a stabilizing reflex influenced by conditions in the skin itself. The center in the brain controls heat elimination so as to compensate for the variations in heat production within the body, and the cutaneous factor adjusts the skin to changes in the atmospheric conditions which affect the rate of cooling from the skin. The blood vessels and sweat glands of the skin are acted upon directly by conditions in the skin. But the activity of this reflex is in turn influenced by the center in the brain.

The controlling center in the brain acts like a thermostat. It responds to changes in the temperature of the blood flowing through it. A rise in this temperature causes the center to decrease the strength of the impulses which normally constrict the vessels in the skin, thus allowing them to dilate so as to afford a larger blood flow and greater heat loss. A fall in the temperature of the blood results in a constriction of the vessels so that the loss of heat is lessened.

The stabilizing reflex influenced by conditions in the skin is not adjusted to regulate the skin to any fixed temperature. The center in the brain influences this reflex, so that instead of a fixed skin temperature it maintains a certain rate of loss of heat. It does this by altering the size of the vessels and the secretion of sweat in accord with variations in the cooling power of the air acting upon the skin.

If the surroundings are cool, the redness of the skin and the secretion of sweat are less evident than if the surroundings are warm, for the skin does not, under the cool surroundings, need to make the same effort in order to produce the necessary dissipation of heat. The local reaction of the heat-regulating mechanism is seen when the skin becomes red and also perspires on only a limited area as a result of warming, such as placing only the hands in hot water.

Chemical Regulation of Body Temperature.

Both the center in the brain and the reflex control from the skin can excite the chemical control of temperature. This control is called into play by the center when the temperature of the body falls below normal, and by the sensory impressions from the skin when the rate of cooling from the surface becomes excessive. The action of the thermostatic center in the brain stimulates the muscles to a greater tonicity and finally to shivering as a means of increasing the temperature of the body. Similarly, the reflex from the skin stimulates the muscles in order to prevent too great cooling of the skin, even though the body temperature is not depressed. The close correlation between the temperature of the skin and the state of tone of the muscles and hence the incentive to muscular activity is an important aspect of the influence of climate.

The external temperature at which the physical regulation becomes inadequate to control body temperature and must be aided by the chemical control is called the critical temperature. It varies somewhat in different individuals, but for a naked man the chemical control is called into play when the room temperature drops appreciably below 70° F. at ordinary indoor conditions of humidity and air movement. The critical temperature is modified by clothing, and it is customary to vary the amount of clothing with the climatic conditions so as to keep the temperature of the skin above the critical temperature.

Water conducts heat better than air; it has a cooling power some twenty times greater than air. A cold bath, 40° F., excites the chemical control of temperature to increase the metabolism to nearly twelve times that of the resting level—an elevation comparable to severe exercise. After a few minutes of exposure to water at this low temperature, chemical regulation becomes depressed and the temperature of the body falls. A cold plunge on getting out of bed is a strain and shock to the system which may be tolerated by young and active individuals, but it may not be desirable for those who lack vigor or who are aging. The shock of the cold plunge may be minimized by first warming up the body with exercises or by starting with a warm shower and gradually lowering the temperature. A cold plunge becomes undesirable when it leaves the individual chilled and shivering instead of warm and invigorated.

Cooling by Evaporation.

The evaporation of water from the skin is a most effective means of cooling. Each gram of water requires 0.54 kilocalorie to convert it into vapor. During a day of strenuous exertion under hot surroundings as much as ten pounds of water may be lost through the skin, although much of it may not be evaporated. Man and the horse are among the few animals which have general sweating. Other animals, notably the dog, lose heat by the evaporation of saliva from the tongue in panting.

Perspiration is continually secreted upon the skin. But when the body is cool and heat dissipation is largely effected by conduction and radiation, the small amount secreted evaporates rapidly and is not observed. Such perspiration is known as insensible perspiration. It becomes apparent if an area of the skin, such as an arm, is inclosed in a glass jar, for the air in the jar becomes saturated with moisture and dew is deposited upon the sides of the vessel.

As the temperature of the skin rises, as a result of either external heat or exertion, the secretion of perspiration is increased. When the rate of evaporation is not sufficient to remove the water as rapidly as it is secreted, the perspiration becomes apparent as beads of moisture or as a film over the surface. Sweat which is not evaporated not only is a waste of fluid but it may also involve a considerable loss of sodium chloride.

When the skin has become bathed with sweat as a result of exertion or warm surroundings, time is required for the moisture to evaporate even after the exertion has been stopped or the surroundings have become cool. The skin may be cooled excessively by this delayed evaporation. As a result the body is chilled, the vessels of the skin constrict and the muscles which have been exercised tend to become stiff and sore. In cooling off after an exertion associated with much sweating, it is advisable to dress warmly until the sweat has evaporated or to wipe the body thoroughly, or best of all to take a shower (not prolonged if cold) followed by a brisk rub and dry clothing.

A man nearly naked and with adequate water to drink can maintain a normal body temperature in perfectly dry air at a temperature as high as 250° F. In such surroundings water will boil and meat will cook. When the air is fully saturated with water vapor the highest temperature to which the body can adjust, even during rest, is well below 98° F. At a temperature near or above that of the body, heat loss depends entirely upon evaporation. As the humidity of the air rises, the ability to lose heat by evaporation is proportionately decreased. In

moist air at high temperatures the body cannot cool by either of its physical mechanisms; the temperature then rises, for the body has no power to suppress its heat production. The reverse of chemical regulation does not occur. The metabolism is not diminished as a result of rise in temperature, but instead it is augmented, according to the principle of chemistry that reactions are accelerated with rise of temperature. In a hot and moist atmosphere there is a disinclination to any exertion; but if exertion is forced, the temperature of the body is markedly and even dangerously elevated.

Heat Cramps.

Under high temperature the excessive loss of salt from the body in sweat may lead to heat cramps. The concentration of salt in sweat varies between 0.2 and 0.5 of one per cent; it tends to rise when sweating is profuse and long continued. If hard work is performed under hot surroundings more than an ounce of salt may be lost from the body in a day. Unless this salt is replenished in the diet the concentration in the blood and tissues falls; heat cramps then develop.

Heat cramps occur in men who exert themselves in hot surroundings. The condition is especially common among stokers in steamships, and in men who work in foundries and steel mills. The cramps occur in the muscles of the legs and arms and often also in the abdomen. Any movement or pressure brings on a paroxysm. The attack may last from twelve to thirty-six hours, and for some time afterward the muscles are sore. In order to prevent heat cramps salt or salty foods should be eaten or the thirst quenched with water or other beverages containing 0.2 of one per cent or more of salt.

Fat in Relation to Heat Loss.

A layer of fat envelops the tissues of the body and separates them from the skin. The thickness of this layer varies in different individuals and in different parts of the body. Fat serves as a heat-insulating material. Although it has only one-ninth the insulating value of air, it nevertheless has three times the insulating value of water. Most of the tissues of the body other than fat are composed largely of water and their conductivity is comparatively high.

Although most of the heat dissipated by the body is brought to the skin by the blood, nevertheless some heat reaches the skin by conduction through the layer of fat and is added to that brought to the skin by the blood. This heat loss is not directly subject to control as is the

heat brought in the blood. Therefore, a deposit of fat either excessively heavy or excessively thin has disadvantages at the extremes of temperature. Obese men are able to withstand cold better than are lean men. In aquatic animals, such as seals and whales living in Arctic waters, the layer of fat beneath the skin is extremely thick and forms an important barrier to the loss of heat. These animals maintain a normal temperature in the interior of their bodies while surrounded by a medium which has more than twenty times the heat-conducting power of air and is at a temperature of 32°F. Although the lean man usually fares better than the fat man in warm surroundings, there is one exception to this. Under the rare conditions in which the temperature and humidity are such that heat cannot be dissipated from the body, the obese man has somewhat the advantage; his greater bulk of inactive tissue allows a slower rise of body temperature and his greater storage of water delays the dehydration of his tissues by sweating.

Clothing in Relation to Heat Loss.

Heat production in the resting state is not sufficient to balance the minimum heat loss from the naked body during rest, if the surrounding temperature is below 70°F. The humidity of the air, the velocity of the wind and, to some extent, the hardiness of the individual determine this minimal surrounding temperature below which chemical regulation must be called into play. During exercise much lower temperatures can be tolerated without excessive loss of heat. During swimming, for example, the temperature is maintained by the extra heat production of the exertion, although the naked body may be immersed in water at a temperature of 60°F. or even lower.

Clothing diminishes the heat loss and forms an important factor in the regulation of the temperature in man. In temperate climates we largely remove the necessity for chemical regulation by keeping the skin covered. Only about 20 per cent of the surface is normally exposed to the air; the remainder is maintained at a tropical temperature by the layer of clothing. A thermometer placed beneath the clothing of an individual who is comfortably warm registers only a few degrees below body temperature; a similar temperature is found beneath the bed covering at night. Each individual thus maintains about the greater part of the body his own "private climate," which, moreover, is a tropical climate. Even the Eskimo, dressed in furs, lives for the most part in this tropical climate. The fur on animals and the feathers on birds are analogous to the clothing of man.

The insulating property of clothing is largely determined by the amount of air which is held in the interstices of the fabric. If it were possible to surround the body with a layer of air held stationary, better protection would be afforded than by any other material. Furs, feathers, and most porous materials are poor conductors of heat because of the relatively great amount of air which they enmesh. Fur consists of approximately 98 per cent of air by volume, so that fur really consists of air with some 2 per cent of hair. Similar relations in varying degrees hold for other materials. The accompanying table gives the coefficients of conductivity of some common clothing materials. The coefficient of conductivity is expressed as the amount of heat in small calories which, in one minute, will be given off from an area of one square centimeter of the material one centimeter thick, when there is a difference of one degree centigrade in the temperature of two surfaces. A low coefficient signifies high insulating properties.

TABLE XIII.—CONDUCTIVITY OF SOME CLOTHING MATERIALS

Substance	Coefficient of Conductivity
Air	0.0000532
Feathers (eiderdown)	0.0000574
Knitted wool	0.0000650
Smooth silk fabric	0.0000684
Smooth wool fabric	0.0000686
Hair	0.0000763
Smooth cotton fabric	0.0000810
Knitted cotton	0.0001002
Linen	0.0001158

Beasts and birds vary the insulation afforded by their hair or feathers by increasing and decreasing the amount of air retained stationary in their coats. In cold surroundings the hair or feathers are held more erect and the thickness of the layer is thus increased. A similar mechanism, although ineffective, exists in man. The minute projections, known as goose flesh, which appear on the skin as a result of chilliness or emotion, are formed by the pull of the muscles attached to and tending to erect the hairs.

A densely woven cloth does not absorb the moisture from the skin; it does prevent ventilation and the evaporation of this moisture. In hot weather porous cloth next to the skin, so as to absorb moisture and permit its ready evaporation, is particularly important. Rubber coats or shoes lack absorption, prevent ventilation, and thus cause the skin to become hot and sodden in warm weather, but clammy in cold weather. If the garment worn next to the skin becomes thoroughly wet the evap-

oration of sweat in warm surroundings is largely prevented, to the great discomfort of the wearer, while in cold surroundings the heat loss by conductivity through the wet material is greatly facilitated and chilliness results.

Artificial Heating.

So far as heat losses are concerned, artificial heating of the air of buildings serves the same purpose as clothing. The heating cannot be used advantageously to replace clothing entirely, for a temperature suited to the occupant when sedentary would be so warm as greatly to handicap physical exertion. The indoor temperature is merely brought to a point at which the parts of the body ordinarily exposed, such as the hands, are comfortably warm and dry without a protective covering. Clothing and artificial heating of houses diminish heat loss, but are not, strictly speaking, means of regulating body temperature. They are rather to be regarded as methods of conserving heat, so that the chemical regulation of temperature is rendered unnecessary, and the heat loss is reduced to a degree which permits an efficient automatic operation of the physical regulative process. The discussion of indoor temperature is covered in more detail in Chapter XIX, dealing with climate and air conditioning.

Sensations of Warmth and Coldness.

Sensations of warmth and coldness are not reliable indications of the temperature of the body; they are indications only of the temperature of the skin, as is illustrated in the sensation of chilliness at the commencement of fever. When alcohol is taken, a sensation of warmth is experienced, although the temperature of the body actually falls. The temperature of the skin at which a sensation of cold is experienced may be modified by long exposure to cold surroundings, so that certain areas of the skin, such as the hands and face, become relatively hardened. This hardening to cold should not be attempted for infants or young children. The heat-controlling mechanism is not fully developed at birth; the body temperature of an infant may rise or fall considerably if the covering is too great or too little.

The only reliable index of body temperature is a so-called clinical thermometer. A temperature appreciably above or below the normal for the time of day (see page 451) indicates a disturbance in the balance between the production and dissipation of the heat of the body. Such a deviation of temperature does not necessarily indicate

illness or infection. In taking a hot tub bath with the body well immersed, the temperature may rise to 104° or even 106°F. The temperature soon drops on emerging from the bath. Because of the efficiency of the chemical regulation of temperature it is more difficult to produce a fall of temperature than a rise. The chemical control is, however, abolished during surgical anesthesia and in deep unconsciousness produced by alcohol, carbon monoxide, and narcotic drugs. Unless precautions are taken to keep the body warm under these conditions, the temperature falls. Alcohol in amounts insufficient to produce unconsciousness interferes with the physical regulation of temperature. The vessels of the skin become dilated and the skin appears warm, moist and flushed. The body temperature falls, but the chemical regulation of temperature, although capable of operating, is not called into play because of the warmth of the skin.

Heat Exhaustion.

The harmful effects of warm surroundings do not arise primarily from an elevation of body temperature, but from the strain put upon the heat-regulating process in attempting to prevent this elevation. The ability to withstand the strain thrown upon the heat-regulating process varies greatly in different individuals. Some persons tolerate repeated and prolonged exposure to heat without serious consequences, although during the time of the exposure their physical ability is greatly diminished. Other persons, particularly children, succumb readily to excess of heat and may be seriously injured by relatively slight strain upon the regulating mechanism. They may even collapse before their body temperature has become appreciably elevated. The necessity for maintaining a large flow of blood through the skin to cool the body throws a burden upon the heart; individuals with weak or defective hearts are particularly susceptible to excessive heat and collapse when the already overburdened heart fails to carry the added load. Those who are weakened by ill health withstand heat poorly, as do those who use alcohol habitually.

There are also certain individuals who, without any apparent predisposing cause, are severely affected by temperatures which are tolerated without discomfort by normal individuals. They are said to be heat sensitive or cold sensitive. The ill effects they experience often take the form of mild exhaustion with weakness and dizziness. The effects may also resemble those of an allergic reaction; individuals so affected may vomit, develop attacks of asthma or even a skin rash.

In some who are especially sensitive an attack may be precipitated on putting an arm in hot water.

Heat exhaustion occurs in the tropics, especially in damp, low-lying regions, in temperate zones during protracted heat waves when the humidity is high, from exposure to humid artificial heat in bakeries and laundries, in the boiler rooms of steamships, and wherever men work under similar conditions. Many persons who show the milder form of heat exhaustion during hot weather become depressed physically and are unable to work or eat. In children this condition is often associated with gastrointestinal disturbances and fever. In more serious cases of heat exhaustion, or, as it is usually called, heat prostration, there are giddiness, nausea and staggering gait; the face becomes pale, the heart beats feebly, and unconsciousness may follow. The skin is clammy with sweat, but the temperature of the body is often reduced and may be as low as 95°F. When heat exhaustion occurs in otherwise healthy men, as among stokers, recovery is usually rapid; but in less healthy persons the condition may pass into unconsciousness and even death.

Heat exhaustion is a form of collapse similar in its general nature to the shock which occurs after a severe injury or hemorrhage. The essential feature is a decrease in the tonus of the muscles, with a corresponding weakness and fall in heat production. Similar though less extreme weakness, but also with subnormal temperature, occurs during convalescence from severe illness and following surgical operations. The low body temperature is not a cause but only one of the symptoms of the condition.

Sunstroke.

Sunstroke, or thermic fever, occurs as a result of excessive exposure to the direct action of the sun; those who do hard work or otherwise exert themselves, especially if they are warmly clad, are particularly liable. The condition does not arise from the sensible heat of the air alone, but is in part due to the action of the sun's rays. The condition varies in severity; in extreme cases it may develop so rapidly that the man falls as though struck on the head and dies in a few minutes. The common form commences with headache and a feeling of depression. Vision is often disturbed, so that everything seen appears colored, usually red. Insensibility follows, brief in mild cases, but in severe cases persisting and even passing into death.

The appearance of a man with sunstroke is distinct from that of a

man with heat exhaustion. In the latter the functions of the body and its temperature are decreased, while in sunstroke they are stimulated to a high degree. The man's face is flushed, the skin is hot and dry, the pulse is rapid; the temperature rises to 110° or even higher. A third or more of those suffering from serious sunstroke die. Recovery may be complete, but in most instances an inability to bear high temperatures persists. Others show later a partial loss of the power to concentrate and a failure of memory, and these symptoms are exaggerated in hot weather.

Heat exhaustion and sunstroke are treated by opposite methods, the one by warmth and stimulation and the other by cold applications. The man with heat prostration is brought into fresh air and wrapped warmly. If he is conscious he may be given hot coffee. In severe cases where the temperature is markedly reduced a warm bath is beneficial.

For sunstroke it is important that treatment should be immediate, for when the unconsciousness and fever persist for any length of time the likelihood of recovery is seriously lessened. The man is taken to a shady place and put on his back with his head raised. An effort is then made to reduce his temperature by applying cold water or ice to his bared skin. The water may be dashed over him from a bucket, applied with a hose, or he may be placed in a bath of cold water until his temperature subsides and consciousness returns.

It is important to note that the unconsciousness resulting from sunstroke is the only form of unconsciousness in which water should be dashed over a man. The application of water as a form of "shock" to revive a man who has fainted, or one who has become unconscious from any cause other than sunstroke, is contrary to correct first-aid treatment. No form of shock is advisable, and particularly not one which wets and thereby chills the victim of any other accident or condition. In sunstroke the application of water is intended not as a shock, but to reduce the temperature.

Fever.

The elevation of body temperature which occurs in many diseases is due to a derangement of the heat-regulating center. At the beginning of the fever the blood vessels of the skin contract and diminish the loss of heat. The skin becomes cold and pale, or even bluish. The cooling of the skin produces a chilly sensation, although the body temperature is elevated. At times the chilliness excites the chemical regu-

lating mechanism and shivering occurs. In some fevers, and particularly in malaria, the shivering is marked and is given the name, ague.

The most common cause of fever is infection; the rise in temperature results presumably from the action of material produced by the bacteria. Infection itself is not essential for the production of fever. Many protein materials injected into the blood cause an elevation in the temperature; thus a high fever follows an injection of milk. Likewise when some of the body's own tissue is killed and absorbed, fever results even though there are no bacteria present in the dead tissue. Thus fever results from the absorption of material from a large burn or from a hemorrhage beneath the surface. Fever temperatures are not as a rule sustained, but tend to fluctuate; the course of the fluctuations is characteristic of certain diseases and thus assists in diagnosing the disease causing the fever.

The body tolerates any reasonable elevation of temperature without serious consequences. The fevers of sunstroke which rise to 110°F. and higher may exceed the toleration of the body and cause death, but temperatures of such dangerous height are rarely reached in fevers arising from infection. A high fever is regarded as a grave sign in an infectious disease because it indicates a severe infection rather than because of any danger from the fever itself. The fever may actually assist in the control of the infection. The growth of many parasites is inhibited at a temperature only a few degrees higher than that normal to the body; it is probable also that fever increases the formation of immune bodies in the tissues and blood. Considerable success has resulted in treating some diseases, especially syphilis of the nervous system, in which fever does not occur, by deliberately inducing fever. The artificial fever may be brought about by injections of foreign protein, by infection with malarial parasites which are subsequently killed with quinine, and by passing high-frequency electrical currents through the body.

When the fever of disease is of no benefit in overcoming infection and brings discomfort to the sufferer, measures may be taken to lower the temperature. Cooling can be increased by rubbing alcohol on the skin and allowing it to evaporate or sponging the skin with cool water. Medicaments called antipyretics lower the temperature in fever. Aspirin is an antipyretic; it increases both sweating and the amount of blood brought to the skin to dissipate heat.

The elevation of temperature in fever excites the body's metabolism to more than normal activity. Thus in severe fever the basal metabolism

may rise to two or three times the normal level. The increased metabolism involves a greater consumption of the fuel of the tissues, and the man with fever loses weight unless he is fed large quantities of food. A hundred years ago it was the practice to starve patients with fever and to let them have very little water. They became emaciated and suffered intensely from thirst; the debilitated condition thus induced undoubtedly increased the mortality. Today, with broader knowledge, it is the general practice to feed fever patients large quantities of nourishing and easily digested food and to give them all the cool water they will drink.

CHAPTER XIX

CLIMATE AND AIR CONDITIONING

THE ACTIVITIES OF MAN ARE GREATLY INFLUENCED BY THE CONDITION OF the air about him—the climate. Extremes of temperature such as occur in the arctic regions and the tropics are definite handicaps to activity; the same is true of the seasonal heat and cold of the temperate regions. The discomfort experienced and the inability to work under conditions of high and low temperatures are merely the extremes of physiological effects which develop not when they become apparent but instead progressively as the atmospheric conditions depart from the optimum for activity. The effects of slight variations from the optimum may not be obvious, but they nevertheless exist. In spite of man's apparent adaptation to a wide range of climatic conditions, the fact remains that for any of his activities the conditions which place the least handicap upon his exertions are narrowly limited. Man can endure adverse climatic conditions and continue to carry out activities, but the adaptation is at the expense of efficiency. A slight change in climate may have a marked effect on comfort and productivity.

In contrast to the great variations in the climatic environment of body, the conditions within the body—what may be spoken of as the internal environment—are kept precisely uniform. The temperature to which the body is exposed may vary more than 150°F.; the temperature within the body normally varies at most only a degree or two. The maintenance of this uniform body temperature under the wide range of climatic conditions and the wide range of heat productions by the body involves constant adjustment by the heat-regulating mechanism. This mechanism, dealt with in the previous chapter, is closely correlated with many vital functions; its operation has far-reaching effects upon the nervous system, circulation, respiration, muscle tonus, glandular secretion and even digestion. The greater the adjustment the body must make to climatic conditions, the greater the demand put upon the vital functions and the greater the diversion of their energies from productive effort.

Beliefs Concerning Bad Air.

In order to obviate the extreme handicaps of adverse climatic conditions, particularly those of cold, man in temperate regions lives and works indoors. Even in the artificial climate he creates he may experience discomfort and limitation of activity because of the condition of the air. Such effects are particularly noticeable in rooms where many persons are present. The air tends to become vitiated. The explanation for this change led in the past to the suggestion of three possible causes, all erroneous, but nevertheless dealt with here because many people still hold to one or more of these scientifically untenable views. These three possibilities were: (1) that oxygen was abstracted and that the percentage of this constituent fell to a level which was detrimental to comfort and health; (2) that the carbon dioxide exhaled poisoned the air; and (3) that some volatile poison emanated from the body either in the exhaled air or through the skin.

Fallacious Conception of Oxygen Deficiency.

The idea of oxygen deficiency was never very strongly championed. A little calculation serves to dispel it entirely. If ten men were inclosed in an air-tight room ten feet long, ten feet high, and a little over ten feet wide, they could exist for many hours without a dangerous depletion of oxygen being produced. The room described contains (in addition to the bulk of their bodies) 1000 cubic feet of air, and of this 21 per cent, or 210 cubic feet, is oxygen. The average man at rest consumes about half of a cubic foot of oxygen each hour; the ten men would consume five cubic feet in this time. After the men had been in the room eight hours, 40 cubic feet of oxygen would have been abstracted from the air and 170 would remain. Instead of 21 per cent of oxygen there would be 17 per cent. No immediate discomfort results from breathing air in which the oxygen has been reduced to 17 per cent. This percentage is equivalent to the pressure of oxygen normally found in air at a barometric pressure of 615 millimeters, or approximately that of Denver, Colorado, where many invalids go for the sake of the climate. Furthermore, the conditions here described as applying to the ten men in a small room are more rigorous than those which would occur except under such special conditions as inclosure in a metal vault. Rooms constructed of ordinary building material are not air-tight, for the air passes through cracks and even through the pores in plaster walls. In an ordinary room with plastered walls the men could live almost indefinitely without suffering from want of

oxygen. If additional evidence is needed it is afforded by such facts as the following: In some mines the percentage of oxygen in the air is deliberately kept down to 17 per cent in the hopes of preventing the explosion of coal dust, although this is a crude and unwise method of prevention.

Fallacious Conception of Excess of Carbon Dioxide.

The idea that carbon dioxide from the exhaled air accumulates in the air of rooms and gives it its detrimental character was disproved more than fifty years ago. Nevertheless, some textbooks in the field of heating and ventilation engineering still contain such statements as: "Carbon dioxide is constantly being diffused through the air of rooms, rendering it unfit for use.". Carbon dioxide in very high concentrations is indeed an asphyxiant, but just as "water cannot rise above its source," so the body can scarcely produce an asphyxiating concentration of carbon dioxide. Even in the worst-ventilated rooms it rarely rises above 0.5 of one per cent. The air in the lungs normally contains between 5 and 6 per cent of carbon dioxide. The concentration in pure outdoor air is between 0.03 and 0.04 of one per cent. The inhalation of one per cent of carbon dioxide is without noticeable effect on a man at rest, although it is noticeable when he works. Two per cent causes only a moderate increase in breathing, and in some breweries the concentration in the air has been maintained at that level without causing any ill effects. Five per cent of carbon dioxide causes an uncomfortable increase in breathing; and very high concentrations, such as are found in silos containing fermenting corn, may cause death by asphyxia, but this effect is essentially due to lack of oxygen.

Much that has been said concerning the vitiation of air by the abstraction of oxygen applies equally to the vitiation of air by the addition of carbon dioxide due to breathing. The percentage of carbon dioxide in the air rises as fast, or nearly as fast (in the proportion of about 0.8:1), as the percentage of oxygen falls; therefore in the extreme example given of the ten men in the small room for eight hours, the carbon dioxide would rise to about 3 per cent.

Fallacious Conception of a Poisonous Emanation from the Body.

Although the idea that carbon dioxide is the principal factor in ventilation is thus disproved, standards of ventilation have, even to the

present time, been based on the amount of carbon dioxide in the air. Carbon dioxide, although not poisonous itself, was long believed to afford a measure of the contamination of the air by a hypothetical noxious organic substance emanating from the occupants of the room. The more carbon dioxide, the more noxious organic matter was supposed to be in the air.

The conception of an organic emanation was a natural development from the ideas of the contagion of disease prevailing before Pasteur established the conception of bacterial infection. When bacteria were unknown, many diseases were attributed to bad air, particularly night air. It was believed that the mist or miasma that arose from swamps carried with it malaria, for the part played by the mosquito was unrecognized. When the bubonic plague (the "Black Death") reached London, great fires were kept burning in the streets to purify the "bad air" which was supposed to cause the disease. Even in the third quarter of the nineteenth century sewer gas from drain pipes was supposed to cause typhoid fever and scarlet fever; in England the soil pipes are still placed on the outside walls of the houses. The idea of poisonous emanations from the body was suggested also by the odor of fetid breath and unclean skin common in crowded and unventilated rooms. These odors are disgusting, but they are not poisonous. Like the smell from sewers, so-called sewer gas, they are harmful only when they contain a spray of bacteria.

Perhaps the most effective disproof of the emanation theory was a simple experiment conducted in the following manner: A man was placed in a small air-tight chamber and breathed air from outside through a tube. A second man was placed outside the chamber, but breathed the air from within the chamber through a tube. The man in the chamber became uncomfortable, although he was breathing fresh air; the man outside was entirely comfortable, even though he was breathing the foul air. The man inclosed and breathing the air of the chamber experienced a change from discomfort to comfort when an electric fan was started.

Discomfort Due to Physical Properties of the Air.

Such experiments afford a fundamental demonstration of the modern theory of what constitutes bad air. It is not the chemical nature of the air breathed, but the physical characteristics which make it uncomfortable and injurious. The temperature within the chamber was 75°F. and the humidity 89 per cent, while the air outside the

chamber was at a lower temperature and much dryer. When the fan was run the cooling power of the air was assisted by its motion.

Atmospheric conditions exert their effects upon human health and comfort chiefly through their influence upon the dissipation of heat from the surface of the body. Four physical properties of the air are concerned in its cooling powers: temperature, humidity, velocity or movement, and radiant heat. The last factor has been generally neglected in studies of ventilation. Little is known of the effect of radiant heat other than that it may contribute much to comfort in otherwise cold surroundings, such as the difference between areas shaded from the sun and those exposed, a difference particularly noticeable at high altitudes. Radiant heat appears to stimulate the activity of the skin to a greater extent than does a similar amount of heat gained through conduction.

The body loses heat by radiation, conduction and evaporation. The amount of heat lost by radiation is determined by the difference between the temperature of the skin and that of surrounding objects. The amount of heat lost by conduction depends both upon the difference in temperature and upon the movement of the air in contact with the skin. The heat lost by evaporation is, to the extent to which sweat is secreted, dependent upon the humidity of the air and the rate of air movement. The movement of the air greatly influences the loss of heat both by conduction and by evaporation; it replaces both the air warmed by the body with cooler air, and the air moistened by the evaporated sweat with dryer air.

The famous incident of the "Black Hole of Calcutta" is often cited, and erroneously so, as an example of the effects of chemical vitiation of the air by the occupants of a room. On a summer night in India a number of prisoners were crowded into a basement room. There were windows which were small but adequate to admit all the air needed for the respiration of the occupants. The heat and moisture produced by the individuals crowded together in the room raised the temperature and humidity of the air to such an extent that most of the prisoners succumbed to heat exhaustion. They were not asphyxiated.

Wet Bulb Thermometer.

The ordinary mercurial thermometer records the temperature of the air; the wet bulb thermometer (described below) gives, in relation to the dry bulb reading, a measure of the humidity of the air, and thus indicates the drying power of the air. By the term "relative humidity"

is meant the amount of water vapor which the air holds in relation to the total amount that it is capable of holding at the prevailing temperature. The latter amount is determined by the vapor pressure of water, which in turn is determined by the temperature. The partial pressure of water vapor is the same, and the weight of water is the same, in air of any barometric pressure, high or low, as it would be in water evaporated in a vacuum. At 86°F. the vapor pressure of water is 26 mm., alike at sea level and on a high mountain. Air or vacuum saturated with water at this temperature contains 30 grams of water per cubic meter (0.3 oz. in 38 cubic feet); at 50°F. the vapor pressure is 9 mm. and the air contains 9.3 grams of water per cubic meter. At the two temperatures the air contains widely different amounts of water, but at each temperature it is 100 per cent saturated. If, however, the air at 50°F. is heated to 86°F. without the addition of water, the pressure of water vapor still remains at 9 mm. This air is then capable of evaporating water up to an additional 17 mm. of vapor pressure. The warmer air would not be fully saturated, and its relative saturation or relative humidity would be 34.6 per cent $\left(\frac{9}{9+17}=\frac{9}{26}=0.346=34.6\right)$. The warm and now relatively dry air would therefore evaporate twice as much more.

The wet bulb thermometer consists of an ordinary mercurial thermometer with the bulb inclosed in a tightly fitting sack of fabric. The lower end of the fabric extends beyond the bulb and dips into a container of water, thus serving as a wick to keep the cloth about the bulb moist. The evaporation of water from the surface of the cloth over the bulb of the thermometer cools it, so that a temperature is recorded lower than that found with the ordinary dry thermometer. The thermometer should be fanned or swung in the air. When the air is fully saturated with water vapor both thermometers register the same temperature. For lesser amounts of moisture the difference in reading depends upon the humidity. The cooling effects of air upon the body follow the wet bulb much more closely than they do that of the ordinary type of thermometer.

Equivalent Conditions of Temperature, Humidity and Movement of the Air.

The cooling capacity of the air is determined by the relations of humidity, temperature and movement. The air maintains the same degree of cooling power as long as the combined effect of these three

factors remains unchanged, although the values of the separate factors may vary considerably. Thus a rise in temperature may be counteracted by a suitable increase in the movement of the air or by a decrease in the humidity. Combinations of temperature, humidity and movement which produce the same cooling effect on the body are called equivalent conditions. A temperature of 70°F., with the air saturated with moisture and stationary, produces the same rate of cooling for the body as do the conditions at a temperature of 89°F. with the air only 15 per cent saturated with moisture and moving 300 feet per minute; these widely different states of the air are therefore physiologically equivalent conditions.

Effective Temperature.

The conception of "effective temperature" is used as the basis for the comparison of equivalent conditions. The air when fully saturated with water and motionless has an effective temperature which is determined solely by the temperature of the air. Thus air at 70° fully saturated and motionless has an effective temperature of 70°F. Any equivalent condition of the air has also an effective temperature of 70°F. The widely different states of the atmosphere given in the preceding paragraph as equivalent conditions both have effective temperatures of 70°F.

The chart in Figure 76 shows effective temperatures in relation to wet and dry bulb temperatures and movements of the air. This scale was prepared for men wearing ordinary clothing. For men stripped to the waist the effective temperatures here given are several degrees too low; for men clad in heavy clothing such as overcoats, the figures are high.

Kata-thermometer.

The so-called kata-thermometer is designed to indicate the effective temperature. This device consists of a pair of thermometers with very large bulbs filled with alcohol and with the stems graduated from 85 to 110°F. The bulb of one of the thermometers is covered with a silk sack. The bulbs are heated in water to about 110°F., and the uncovered bulb is dried. The time taken for the temperatures to fall from 100°F. to 95°F. is then observed with a stop watch. The loss of heat per square centimeter of the bulb is calculated from the mass of fluid in the thermometer, the area of the bulb, and the rate of fall in temperature. The combined influence of temperature, humidity, air

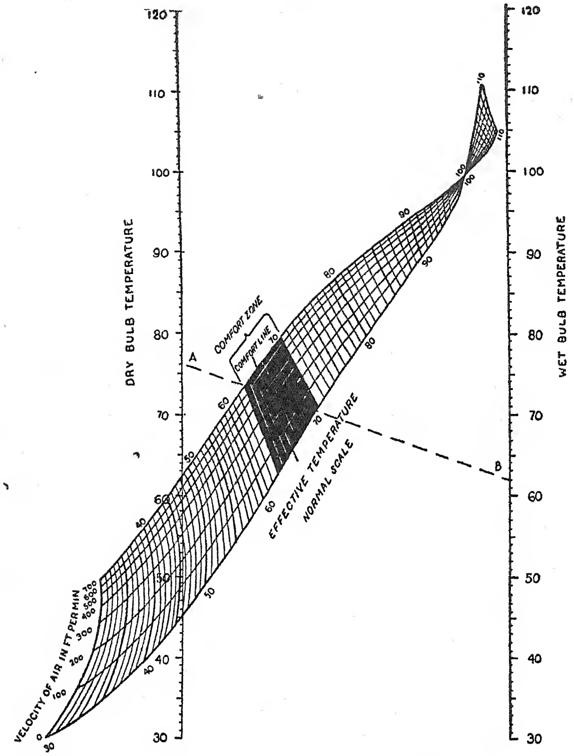


Figure 76. Chart Showing Effective Temperature in Relation to Wet and Dry Bulb Temperature and Movement of the Air.

Examples in Use of Chart.

Given dry bulb 76°, wet bulb 62°, velocity of air 100 feet per minute, determine: (1) effective temperature of the condition; (2) effective temperature with still air; (3) cooling produced by the movement of the air; (4) velocity necessary to reduce the condition to 66° effective temperature.

(1) Draw line AB through given dry and wet bulb temperatures. Its intersection with the 100-foot velocity curve gives 69° for the effective temperature of the condition.

(2) Follow line AB to the right to its intersection with the 0 velocity line, and read 70.4° for the effective temperature with still air.

(3) The cooling produced by the movement of the air is 70.4° — 69° = 1.4° effective temperature.

(4) Follow line AB to the left until it crosses the 66° effective temperature line. Interpolate velocity value of 340 feet per minute, to which the movement of the air must be increased for maximum comfort.

The comfort zone shown as a shaded area represents the effective temperature to be maintained in dwellings, office buildings, theaters, schools, and other places where only light physical activity is carried on.

In summer when thin clothing is worn the comfort line will approach the lower limit of the shaded zone; with the heavier clothing worn in winter it will approach the higher limit.

movement, and radiant heat is believed to influence the heat loss from the body in much the same way that they do that from the kata-thermometer. A heat loss of 6 millicalories per square centimeter on the dry bulb and 20 on the wet corresponds to a generally comfortable condition for sedentary workers. A greater rate of heat elimination is necessary for those engaged in more energetic occupations.

Influence of Heat Regulation upon Work.

Every hindrance to a free elimination of heat either reduces bodily exertion or causes it to be done under a feeling of oppression and a burden of fatigue. A cool skin not only makes possible a greater muscular exertion; it also increases the desire for the exertion. The following observations illustrate the depressing influence of heat. An increase of room temperature from 68°F. to 75°F. with a humidity of 80 per cent caused in one test a decrease of 15 per cent in the work performed by men who were stimulated by a cash bonus. Moreover, greater fatigue followed from the lesser work in hot air than from the greater work in cool air. In another test in which the work was performed under conditions of maximum effort, the output diminished 28 per cent under this same elevation of temperature. The curve of output per man from many factories runs at a definitely lower level during hot summer months than during the cooler seasons.

Stimulation by Local Cooling.

When the entire surface of the body is heated or cooled, the flow of blood to all of the organs of the body is altered. On the other hand, heating or cooling the skin over a restricted area induces a response only in the deep structure correlated with that area of the skin. There is a close connection between the nerves which supply the skin and those which supply the deeper structures. An ice pack placed on the surface of the lower abdomen to treat an inflamed appendix does not, and cannot, cool the appendix directly, for a layer of circulating blood intervenes. The vessels of the appendix, however, become constricted because those of the corresponding skin areas are constricted by the cold of the pack.

Such reactions in deep structures induced by local changes in the temperature of the skin above them are brought about through nervous reflexes. A change in the temperature of any area of the skin gives rise to impulses which go to the central nervous system and influence its action. Cold water dashed against the warm skin causes a stimulating reaction. To a less degree the same effect is produced by varia-

tions in the rate of cooling and evaporation due to shifting air currents. The bracing effect of brisk outdoor air in clear weather is due to the movement of the air and to the variations in radiant heat. Indoor conditions of the air are as a rule monotonous and unstimulating because of a lack of movement in the air. Lack of motion is the greatest factor in causing the air to feel stale and lifeless. The admission of outside air to heated rooms gives freshness by the motion it imparts to the air in the room.

Movement of the air prevents its stratification. In heated rooms the warmer air rises to the ceiling and the colder air falls to the level of the floor. The feet of the occupants are thus immersed in a stratum of cold air, and their heads in a stratum of relatively warm air. This most undesirable condition is counteracted when the air is actively mixed by means of a fan or jets of air.

Bacteria in the Air.

Most air-borne infections require propinquity in order that a sufficiently large amount of the spray of infected saliva or nasal secretion may be borne directly from one person to another. Under outdoor conditions people do not crowd as they do indoors, and the movement of air even on the calmest days is large as compared with that indoors. The spray of saliva is blown away by the movement of the air, so that the infection cannot be massive, as it may be indoors where the air is comparatively still. Indoor conditions are rendered even worse when the occupants are facing one another at comparatively short distances as they are in a railway or street car or across narrow work benches.

The spread of diseases, such as colds, sore throats, bronchitis and influenza, is promoted by the still and heated air indoors. Thus on one troop ship infectious sore throat was ten times as prevalent among the men who occupied three lower decks which were badly ventilated, as among the men on one upper deck which was well ventilated.

Properly designed ventilation, by renewing the air, diminishes the bacterial count; but, what is more important, by creating air movement, it scatters the bacteria so that infection is less liable to occur.

Ventilation.

It is generally possible to impart by artificial means a satisfactory cooling power to the indoor air. Such is not the case, however, with outdoor air. Man is the victim of his climate. The dweller in the tropics bears at all times the added burden of keeping himself cool;

as this burden limits his activities he is slow and inert. People of northern countries with their colder and more variable climate are relatively more vigorous, healthy and ambitious. In history successful invasions of nations have usually occurred from the north, and shifting climatic conditions have influenced the civilization and vigor of entire nations. Even the fluctuations of the seasons in temperate climates have an influence upon the work and health of the inhabitants. The added energy needed to combat heat throws a strain upon the failing forces of those who are ill, and causes mortality peaks to appear after each period of the hot weather in summer.

Recognition of the great importance of the physical properties of the atmosphere upon the activity and health of man opens up many possibilities of industrial betterment. Much improvement has been made recently in the ventilation of factories, offices and houses, but much more remains to be done. The improvement from the conditions in the middle of the last century may be realized best from an example of factory ventilation as described in 1842, presenting the condition of tailors' work in London at that time: "Eighty men in a room fifty feet long by twenty wide, lighted by a skylight, sitting nearly knee to knee, with an atmosphere in summer 20° higher than outside, and the perspiration so running from them as to spoil, at times, the clothes they worked at; while in winter things were even worse, and in the very coldest nights thick tallow candles melted and fell over from the heat. Men fainted at their work and few men there reached the age of fifty years."

The end to be attained by ventilation is to maintain the atmosphere that conforms to the following conditions:

1. Sufficiently warm for comfort, thus obviating the chemical regulation of temperature.
2. Of sufficient cooling power, as determined by temperature, humidity and movement, for free and efficient working of the body's heat-regulating mechanism.
3. Of sufficient movement to be bracing and to minimize the spread of infection.
4. Sufficiently renewed to maintain a low dust and bacterial content.

Methods of Ventilation.

The most difficult of the requirements of ventilation to fulfill is the important one of air movement, not so much mass movement as mixing

and sending little puffs of air this way and that. Most systems of ventilation are designed to regulate the admission of air from out-of-doors and to obtain some degree of circulation in the air, while fulfilling more or less well the other desiderata tabulated above. The admission of air from out-of-doors serves as the simplest method of imparting movement to the air and at the same time effecting the flushing necessary to keep the bacterial count at a low level. The momentum is imparted to the air admitted through ducts or windows either by the natural movement of the air passing between zones of different temperature or by such mechanical means as fans which force air into or exhaust it from the room.

Ventilation by the natural movements of the air, that is, through windows, is more effective in small rooms than in large ones. The ventilation comes from the exposed walls, and small rooms possess a greater area of wall surface in proportion to their capacity than do large rooms; the surface varies as the square, and the capacity as the cube, of any corresponding linear dimension. When there are no special openings for incoming air, it gains access at poorly fitting sashes or under doors. Even when these cracks are tightly closed a certain amount of air will come through the plastered walls. Flues of fireplaces act as ventilating shafts, and their efficiency is greatly increased when a fire is burning. Windows, even when shut, give some movement to the air. Warm air coming in contact with the glass which is kept cool by outside air is itself cooled, becomes heavier, and falls to the floor. This type of movement, although freshening the air, has the objection of contributing to stratification.

Large rooms, particularly those of modern construction with tightly fitting window sashes and asphalt roofs, require special openings for the admission of air. The fact that these rooms often afford a large amount of air space per occupant does not materially improve the ventilation as a whole. Ventilation is, save in the aspect of bacterial contamination, largely independent of the air space allotted to each occupant.

The various methods of admitting air to effect ventilation are illustrated in Figure 77. Diagram 1 of this figure shows a room ventilated by means of an open window, but with no other outlet for the air. Such ventilation leaves a large area of stagnant air in the upper half of the room and a layer of cold air on the floor. If the window is open at both top and bottom a circulation is induced in the immediate vicinity of the window; the incoming cold air falls to the floor and

heated air is forced out at the top of the window. This condition is not conducive to the comfort of the occupants of the room. If radiators are located immediately beneath the windows and the windows are fitted with deflectors, the incoming air is heated, rises, and is short-

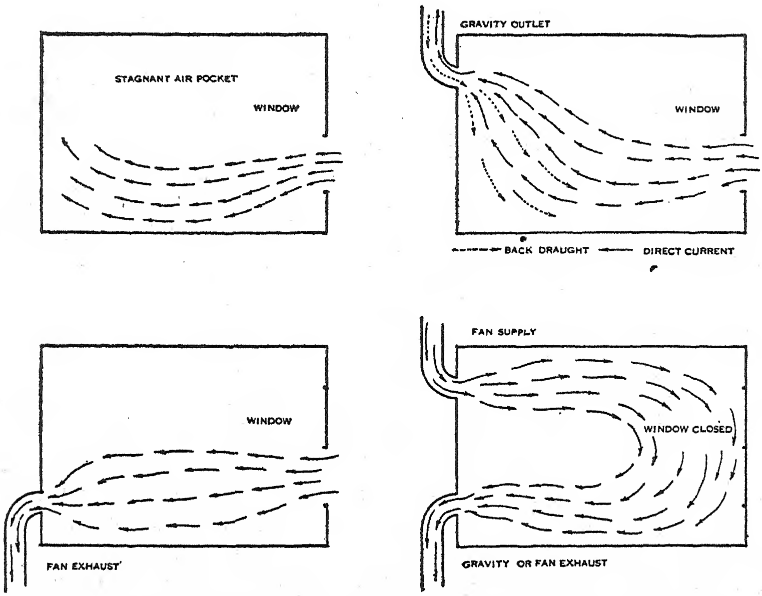


Figure 77. Diagram Illustrating System of Ventilation Discussed in Text.

circuited through the top of the window without sweeping effectively through the room.

In diagram 2 an exhaust duct is added in the wall opposite the window. A channel is thus afforded for the air to escape and the incoming air sweeps across the room. The air circulation is varied by wind pressure. If the wind is blowing toward the open window the circulation is augmented. If the wind force is in the opposite direction, the circulation is slowed. The pressure and direction may be such as to cause a flow of air down the duct and into the room. This method of ventilation is thus subject to variations induced by the weather, and requires constant attention in order to afford satisfactory results, but with such attention good results may be attained.

In diagram 3 a suction fan is introduced into the exhaust duct to insure circulation. The addition of the fan does not prevent variation in the air flow as a result of variation in the wind; it does, however,

prevent back drafts and the lowering of the air flow below a certain minimum. It has the disadvantage of frequently causing a short circuit in the general air flow and in the floor drafts, particularly if the exhaust opening is located at the floor level and if there are inlets in the outer wall at the floor level as in the direct-indirect heating system.

In diagram 4 the air supply is forced by a fan into the room through an outlet near the ceiling. The air stream passes across the room above the heads of the occupants. Air is exhausted from the room with or without the aid of a fan through a duct at floor level and on the same wall as the inlet. As the fan pressure is usually higher than the air pressure acting on the windows, there is a greater tendency for air to leak out of the room than into it.

Air Conditioning.

Strictly speaking, air conditioning consists of any alteration of the physical properties of indoor air to suit it better to the comfort and activities of the occupants of the room—in short, to conform to the requirements of good ventilation as given on page 476. The practice of heating air with open fires, later with stoves and still later with central heating appliances is an attempt at air conditioning; so also is the use of an electric fan in the summer time.

The term air conditioning, however, has in recent years taken on more definitely the significance of cooling as well as heating the air in order to maintain under all external climatic conditions a nearly uniform indoor climate. Trains, stores, theatres, hotels and also private homes are now being "air-conditioned," often with the use of elaborate equipment. The effects of air conditioning to overcome summer heat are as desirable and beneficial as the older air conditioning to overcome winter cold. There are, however, in these attempts to create a year-round artificial indoor climate, several special conditions that have not yet been adequately controlled or about which there is misunderstanding.

One concerns the humidity of the air. Low relative humidity of the heated indoor air of northern regions has received much comment as a possible contributing factor to respiratory infections and nervousness. The air in most heated rooms has a low relative humidity, but usually a higher absolute humidity than outdoor air. The air drawn from outside on a cold day contains little water, although the air may have a relative humidity of 100 per cent. This air when heated retains

the same amount of water; but since it is now capable of holding more water, the relative humidity decreases. When such air is breathed, the nose in moistening it adds no more water than it does to the same volume of air breathed out-of-doors. Less heat is added to the indoor air in conditioning it for the lungs. It is possible that the nose reacts unfavorably to warm air at low relative humidity, but there is no clear evidence to support this fact. It is true that in a head cold the nose plugs up on coming indoors and tends to clear on going out-of-doors. This fact is no indication that the different relative humidities exercise any effect. More probably the changes are due to the cooling effect of the air on the skin rather than the inside of the nose. There is no valid evidence that the low relative humidity of heated rooms exercises any detrimental effect upon health. Desert regions where the incidence of respiratory infections is especially low are dry.

Most attempts to humidify heated air by steam kettles, or water containers on stoves and radiators, may exercise a psychological effect but virtually none on the humidity of the room. It is necessary to evaporate many gallons of water a day to maintain a high relative humidity in an ordinary-sized room. The invigorating and pleasant sensation experienced from the air in greenhouses, which, since the ground is kept wet, is often attributed to the humidity, is in all probability due to air movement rather than moisture. The warm air is constantly cooled by the glass roof and thus constantly kept in motion.

The most evident drawback to air conditioning as now generally practiced is in the too great uniformity of the properties of the air. The temperature-regulating mechanism of the body operates best when there are slight but definite and continual changes in the cooling powers of the air. The maintenance of too uniform air conditions appears to relax the regulating mechanism so that it does not respond well to the severe and abrupt change experienced on going out-of-doors from the air-conditioned room. As a result, an exaggerated sense of the heat may be experienced; sometimes nervous disturbances result.

Climate and Diseases.

One of the most striking phenomena of seasonal variations in the temperate zone is the corresponding rise and fall of diseases. The general death rate shows two regular maxima, one occurring in late summer and the other in late winter. The causes of death are different; in the summer the diseases responsible are intestinal infections and parasite-borne diseases such as malaria; in the winter the diseases are

respiratory infections, diphtheria, scarlet fever and measles. The same distribution of diseases is found geographically, the warm-weather diseases occurring persistently in the tropics and the cold-weather diseases in the northern regions. The organisms of diseases or the parasites spreading them have, like man, optimum climatic conditions.

The treatment of disease by change of climate has, aside from the relief from the depression of heat, some physiological effects. Respiratory infections, scarlet fever, rheumatic fever and arthritis appear to be benefited by warm, dry climates; their prevalence is greatest in regions which are cool and moist. More important, however, than climate is the care which the ill person obtains. Salubrious climates cannot compensate for lack of good nursing care, and such care may more than compensate for an inclement climate. Any benefit from "change of climate" for convalescence or vacations is due more to psychological than to any direct physiological effects.

CHAPTER XX

REPRODUCTION AND THE ORGANS OF SEX

THE ESSENTIAL PROCESS IN REPRODUCTION IS THE UNION OF A MALE cell, or spermatozoon, with the female cell, or ovum. The new cell formed by this union divides into two cells, then into four, eight, sixteen, and so on. These cells then differentiate into the various tissues of the body, and the result is an organism which is a replica of its parents.

Fundamentally, the process of sexual reproduction is the same throughout the range of animal life, and for plants as well. The process by which the spermatozoon is enabled to reach the ovum varies in different classes of animals. The protection afforded the fertilized ovum likewise varies in character and duration. But these variations do not alter the fundamental character of reproduction.

Reproduction in man and in the fish is the same process, but the accessory arrangements by which it is accomplished are widely different. In the fish, reproduction is effected without bodily contact between the male and female. The female fish discharges her eggs into the water or deposits them on the bottom; the male fish merely ejects his spermatozoa in the neighborhood of the eggs. Each spermatozoon swims about until, if successful, it comes in contact with an egg. Then the essential act of reproduction takes place by the union of these elements. The egg of the fish contains a store of food sufficient to feed the newly formed cell until it has developed into a small fish capable of finding its own food. In the human species the spermatozoa of the male are injected into a cavity in the body of the female. The spermatozoa swim in the film of fluid on the moist surface of this cavity until one of them reaches the egg deposited in a passage or chamber opening into this cavity. Then the essential act of reproduction takes place in the union of the spermatozoon and ovum. Unlike fish and birds, the human egg does not contain sufficient nourishment to allow the full development of the newly formed cell. Therefore, the cell remains as a parasite in the mother until it has developed into a child.

Male Reproductive System.

The male reproductive system consists of the testicles, in which the spermatozoa are formed, and an apparatus for conveying and ejecting the fluid semen containing the spermatozoa. From the testicles the spermatozoa pass through a long convoluted duct, the epididymis, and from there they enter a tube, the vas deferens which leads to the urethra. At the time of ejection the spermatozoa are squeezed from the vas deferens into the urethra in the base of the penis; further volume is added by secretion from the prostate gland and seminal vesicles. The collected material, or semen, is then ejected by a muscle which squeezes down upon the urethra.

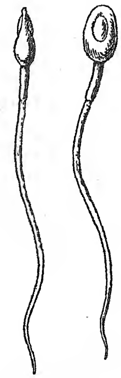


Figure 78. Human Spermatozoon, Side and Front View.

The Testicles.

The testicles are ellipsoid in shape and measure approximately one and a half inches in length and three-quarters of an inch in thickness. They are suspended beneath the pelvis in a pouch called the scrotum. The testicles do not develop in this position. They are formed in the abdominal cavity just below the kidneys and descend from there into the scrotum. The descent is usually completed about two months before birth. In the final portion of this descent, the testicles carry the peritoneum ahead of them and pass through the inguinal rings, the anatomy of which has been discussed under hernia (see page 59).

One or both of the testicles may be stopped in their descent, usually in the inguinal canal, and fail to reach the scrotum. In some animals, such as the elephant, the testicles do not descend, but remain throughout life as abdominal organs; in others, such as the rat, the pouches of

peritoneum which surround each testicle fail to close in the inguinal canal, and the testicles may be drawn at will through the opening into the abdomen, probably a protective measure in fighting.

In human beings the failure of descent of the testicles is known as cryptorchidism (hidden testicle); single cryptorchidism, i.e., one testicle undescended, is present once in about every 1000 infants; double cryptorchidism, in every 12,000. Spermatozoa are not formed in the undescended testicle. The cells from which the spermatozoa develop are

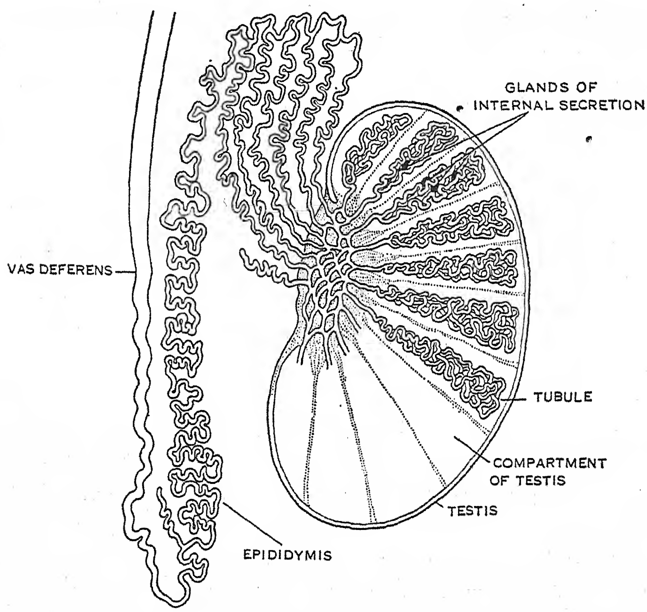


Figure 79. SECTION OF TESTIS, EPIDIDYMIS, AND VAS DEFERENS.

sensitive to slight changes of temperature, and the formation of spermatozoa is stopped at a temperature as high as that of the abdominal cavity. The normally descended testicle surrounded only by the thin walls of the scrotum is at a temperature slightly lower than the interior of the body. Some adjustment is made to changes of external temperature by the contraction or relaxation of the muscle fibers in the walls of the scrotum; in cold surroundings the testicles are pulled more closely in contact with the body, while in warm surroundings the scrotum relaxes and the testicles are moved away.

Failure of descent of the testicles does not interfere with activity of

the glands of internal secretion present within the testicle. Thus while sterility results from uncorrected double cryptorchidism, the development of the secondary sexual characteristics may not be affected. Single cryptorchidism does not cause sterility. Sometimes cryptorchidism corrects itself before the sixth year and in such cases the spermatozoa develop normally. If the condition persists after puberty the ability to produce spermatozoa is rapidly lost. In some instances the medicinal

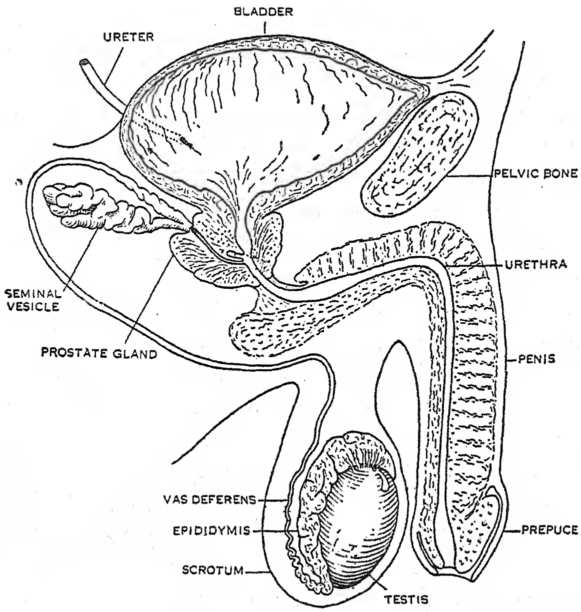


Figure 80. Schema of Male Reproductive System.

administration of an extract of the pituitary gland hastens the descent of the testicles. If this procedure fails, surgical operation becomes necessary and should be carried out soon after the age of six. In rare instances double cryptorchidism associated with imperfect development of the penis has led to error in designating the sex of an infant; the boy is mistaken for a girl, and the error may persist until the development of the secondary characteristics or the descent of a testicle indicates the unfortunate mistake.

The testicle consists of a capsule of strong elastic tissue, the interior of which is divided into numerous compartments by partitions of the same tissue. Long, branching, convoluted tubes fill these compart-

ments. The spermatozoa are formed within these tubes. The cells which line the tubes go through a series of alterations culminating in the formation of the spermatozoa. The essential feature of this process as described in Chapter XXII consists in the division of the cells in such a manner that the chromosomes, the hereditary-bearing elements of the cell, are reduced to one-half the number normal to human cells. In the spermatozoon the chromatin is gathered together into a mass similar in shape to a blunt arrowhead. The mass is essentially the nucleus of a cell; in fact, the spermatozoon is an especially developed cell. Around this nucleus there is the minimum of cellular material, except that on one side a long slender tail is formed. This tail is the organ of locomotion for the spermatozoon; it plays no part in reproduction other than to give to the spermatozoon the motility which enables it to reach the ovum. When the ovum is reached, the mass of chromatin forming the head of the spermatozoon enters and unites with the nucleus of the ovum. The tail, having performed its function, is dropped off.

The Epididymis, Vas Deferens, and Seminal Vesicles.

The convoluted tubules which fill the compartments of the testicle open into a common tube which emerges near the top of the testicle. This tube is several feet long, but is convoluted to such an extent that it is compressed into a small pouch attached to the rear of the testicle and known as the epididymis. On emerging from the epididymis the tube becomes larger and firmer, and is then known as the vas deferens.

The vas deferens from each testicle is about an eighth of an inch in diameter and twelve inches long. It extends from the epididymis to the urethral canal of the penis. In its course the vas deferens goes through the inguinal canal and enters the abdominal cavity. It can be felt on either side of the center of the body as a firm cord passing over the pelvic bone near the external inguinal rings. At this point in its course it passes nearest to the surface of the skin, and it is here that it is cut in sterilizing a male; the severance of the connection between the testicles and the urethra prevents the passage of spermatozoa, but does not otherwise interfere with sexual activity.

The seminal vesicles are small pouches which open out from the vas deferens just before it enters the urethra. These vesicles lie beneath the bladder and in front of the rectum. The urethra constitutes the remainder of the genital passage in the male. Since the urethra is a passage of the urinary as well as the generative system, the spermatozoa are brought into it only when they are to be discharged.

The spermatozoa, as they are formed in the testicles, do not move by their own activity but are carried through the epididymis by the slow peristaltic movement of the tubules. The spermatozoa attain their physiological maturity during this passage and are carried into the vas deferens. The spermatozoa, after attaining their maturity, retain their vitality for a period of days and then gradually decline in vigor and die. In the absence of ejaculation the aged spermatozoa degenerate in the vas deferens and are eventually absorbed. With excessive frequency of ejaculation the spermatozoa are moved through the epididymis too rapidly to permit their attaining full maturity.

During ejaculation the spermatozoa are carried by peristaltic movements through the vas deferens and the seminal vesicles and deposited in the urethra. It is uncertain whether or not spermatozoa in any number are stored in the seminal vesicles; these pouches, however, like the prostate, to be discussed, form a fluid which adds bulk to the seminal discharge. The number of spermatozoa discharged at one time is enormous—200,000,000 is an approximate figure. Nevertheless, the volume occupied by this great number is minute. The spermatozoa, aside from their delicate tails, are no larger than the red blood corpuscles, 5,000,000 of which occupy less than half the volume of one cubic millimeter of blood. The bulk of the seminal discharge is made up of fluid supplied by the seminal vesicles and prostate gland.

The Prostate Gland.

The prostate gland is about the size and general shape of a large chestnut. It is situated at the base of the bladder and surrounds the urethra. The tube leading from the seminal vesicles to the urethra also passes through it and meets the urethra near the center of the gland. A muscular coat surrounds the gland; when it contracts, the viscous secretion is expressed into the urethra.

The secretion, in addition to supplying bulk for the seminal discharge, may enhance the motility of the spermatozoa and also neutralize the acid secretions of the urethra and vagina which are unfavorable to the activity of the spermatozoa.

The prostate gland is small until puberty, when it begins to increase in size; it continues to grow during adolescence. Between the ages of twenty and thirty-five it usually remains stationary in size, but after forty it begins again to enlarge gradually and continues to a maximum between fifty and sixty. This second period of growth is not associated with an increased functional capacity. The fact that the urethra passes

through the prostate is unfortunate, for enlargement of the central portion of the gland tends to constrict the passage. Such constriction, leading first to difficulty and eventually to impossibility of passing urine, occurs in a considerable number of men who have passed middle life.

Many theories have been offered to explain the enlargement of the prostate leading to obstruction, but the cause is not definitely known. It was at one time believed that it might result from early and excessive sexual activity or from gonorrheal infection. The fact that such obstruction is rare in the Oriental races and common only in the Caucasian refutes these assumptions. The additional fact, however, that enlargement is also rare among Caucasians who have led celibate lives and also among eunuchs, strongly suggests that it is in some way connected with sexual activity. Experiments on animals, such as the monkey, indicate that the internal secretions of the testicles, and also of the pituitary gland, may influence the size of the prostate. The possibility has been suggested that enlargement is due to an unbalanced relation of these secretions occurring during the period of declining sexual activity. The high prevalence in some races as compared to others in no way refutes this theory, for other disturbances of internal secretions, such as diabetes and exophthalmic goiter, show racial preferences.

When the urine is suppressed by enlargement of the prostate it is necessary to pass a catheter to empty the bladder. The obstruction may be permanently relieved by removing the gland by surgical operation. Removal of the prostate does not affect sexual desire or sexual potency.

The Penis.

The penis serves to direct the discharge of the seminal fluid. The human penis consists of three cylindrical-shaped masses of erectile tissue bound together with connective tissue and surrounded by a layer of skin. Erectile tissue has a spongy structure and contains cavernous blood vessels. The pressure of the blood filling these vessels determines the size and firmness of the tissues. Two of the cylinders of erectile tissue forming the penis are attached to the bones of the pelvis. The third cylinder of erectile tissue lies below the other two and in the groove formed by their junction. This lower cylinder of erectile tissue is longer than the other two; it is expanded at each end, in the rear to form a bulb and in front to form a conical cap covering the ends of the two upper cylinders, the head or glans of the penis. The urethra passes through this cylinder of erectile tissue.

The urethra is lined with mucous membrane. The skin which covers the penis meets this mucous membrane at the margin of the external opening of the urethra. At the base of the glans of the penis the skin is turned forward in a fold which surrounds the glans and forms the prepuce or foreskin. The skin covering the glans and lining the prepuce contains no hairs, but it retains the grease glands which ordinarily accompany the hairs. The secretion of these glands appears as a whitish solid material. If not kept clean, the prepuce becomes irritated by the accumulation of this material. The operation of circumcision consists in the removal of the prepuce, and is performed when the opening of the prepuce is contracted and retraction prevented. It is also performed as a ritualistic measure in the Jewish and Mohammedan religions. The seminal vesicles and prostate gland open into the bulb formed at the rear end of the lower cylinder of erectile tissue. This bulb is surrounded by muscle. When the muscle contracts, the bulb is compressed and its contents are squeezed out through the urethra.

Sexual Activity.

In order to fulfill its functions of directing the discharge of the seminal fluid, the penis must become rigid. The rigidity results from the distention of the spaces of the erectile tissue with blood under pressure. Small arteries open into the spaces; the outlets to the veins are surrounded with fibers of involuntary muscle. When activated by nervous impulses the arteries dilate, admitting a greater flow of blood to the spaces, and at the same time the muscles about the outlets constrict and impede the discharge of the blood. In consequence the erectile tissue is filled with blood under considerable pressure and distended to the limit permitted by the layer of connective tissue surrounding it. The dilation of the arteries which results in the erection is controlled by nerves from a center near the lower end of the spinal cord. This center is acted upon by sensory impulses arising in the genital tract and by impulses descending from the brain; both mechanical stimulation of the genital tract and emotional excitation can cause erection.

The nerves controlling the discharge of the seminal secretion come from centers located, like those controlling erection, near the lower end of the spinal cord. The discharge is largely a reflex act initiated through the same impulses which bring about erection. During erection and ejaculation sphincter muscles of the bladder are constricted to prevent the entrance of urine into the urethra. The muscular tissue

about the vas deferens, seminal vesicles and prostate gland is stimulated; spermatozoa and secretions are forced into the urethra. The muscle about the urethra is then stimulated to contract intermittently, thus ejecting the fluids from the penis. Nerve fibers from the center controlling ejaculation extend to the brain and other parts of the nervous system. At the time of ejaculation the blood pressure is altered; the heart rate and breathing are accelerated; and there is a strong psychic reaction. The process carried to its completion is known as the sexual orgasm. In the female, orgasm is not accompanied by the discharge of any seminal fluid. Muscles analogous to those about the bulbous portion of the male urethra surround the vagina; at the time of orgasm they contract intermittently.

Sexual excitement leading to orgasm may in either sex be initiated by impulses brought to the centers in the cord by nerves leading from the brain and from the external genitalia. Thus the sight of a sexually appealing person, or even the thought, may arouse the excitement, as may also contact with the penis of the male or the clitoris or vagina of the female. In the male the impulses may arise also from the seminal vesicles and surrounding regions. The vesicles secrete fluid more or less continuously and become distended by the collection. Discharge, accompanied by erection and orgasm, may then occur during sleep in the so-called nocturnal emissions. These involuntary discharges are normal and harmless.

The frequency of nocturnal emissions varies widely with different individuals and at different times for the same individual. They may occur at intervals of a month or more, or several times a week. Attempts on the part of hygienists to set a normal average, as say twice a month, have led to harmful impressions in youths who, although healthy and normal, have emissions more frequently. Young men are often led to believe that the emissions are harmful, that they indicate a loss of "vital energy," that they are weakening and detrimental to "manhood" and that they interfere with athletic prowess. The emissions are in themselves harmless, but the belief that they are harmful actually does harm. The worry which results undermines the young man's confidence in himself as a fit and healthy individual and may make him secretive and moody. Sleeping on the back tends to increase the frequency of nocturnal emissions, possibly because in this position the filled bladder rests upon and presses upon the vesicles and increases the irritation from them. Likewise thinking about sexual mat-

ters, sexual phantasy, while going to sleep increases the likelihood of emission.

What has just been said concerning nocturnal emissions applies in some measure, and to both sexes, to orgasms induced through voluntary excitation of the genital tract, the practice of masturbation. From a purely physical aspect this practice, when carried to great excess, is unquestionably detrimental to health and productive activities as would be an equal excess of sexual activity in a normal manner. Moreover, such excessive masturbation is often accompanied in the male by incomplete activity of the sexual reflexes; full erection does not develop and ejaculation occurs prematurely. Such conditions are harmful both physiologically and psychologically.

Masturbation is rarely carried to harmful excess by the normal and healthy individual. According to older beliefs still unfortunately common, a wide range of abnormalities, particularly nervous and mental, resulted from masturbation. It seems more probable that the actual sequence is reversed, and that the excessive masturbation, instead of causing these abnormalities, occurs as a result of them. It is an unfortunate practice to impress upon boys the idea that masturbation is ruinous to their health and character. Masturbation should be discouraged, but it is doubtful if the doctrine of moral damnation really attains this end. Rather the character and self-confidence of the young man are hurt by what appears to him his lack of will power in yielding to a practice which he has been taught is shameful. In fact, all men have to learn to control this habit in which the majority of adolescent boys indulge to some extent. Irritation of the genital tract due to lack of cleanliness, overeating, lack of sufficient physical exercise, and erotic stimulation from books, pictures and plays are the main excitants to masturbation. Vigorous, regular physical exercise, mental activity and a simple diet are excellent deterrents.

The harmful effects of the long-continued practice of masturbation arise for the reason that it is not a normal or adequate form of sexual expression. Normal sexual activity is not limited to the mere physical orgasm. It is an extensively conditioned psychological process. This conditioning is acquired by experience; the sexual activities in time become fixed by habit. Normal sexual activity involves two individuals of opposite sex; sexual stimulation and the whole process of sexual activity carried through to the completion of the sexual act with the satisfaction of both partners necessitates normal sexual habits. Habitual masturbation is a form of psychological conditioning in which the

habits are directed away from the normal object and the normal procedure of sexual intercourse. The habit thus acquired, if indulged in excessively, may eventually so alter the psychological adjustments of the individuals as to interfere with normal sexual activity and the normal relations of marriage. In the male the conditioning from long-continued masturbation may result in inadequate erection and more particularly in premature ejaculation. In the female the fixation of sexual excitement on the clitoris, to which friction is applied in masturbation, may diminish the response from the vagina and so frustrate sexual capacities in normal sexual intercourse; orgasm does not then occur and sexual excitement is left unrelieved. Under such circumstances a difficult period of sexual reconditioning must be gone through before normal marital relations can become properly established. Maladjustment of sexual relations is a common cause of disastrous marital discord.

In modern civilization, particularly among the higher classes, marriage is not, for economic reasons, common at the early age at which physical sexual maturity is attained. This delay affords greater opportunity for the development of the adverse psychological conditioning of the sexual impulse, as described here for habitual masturbation. Such conditioning is not limited to masturbation, but may occur, although in less degree, from the contact of the two sexes in the mutual but unsatisfied sexual excitement of "petting." This mutual excitation is a normal and proper prelude to the sexual act, but when it is carried out habitually without the completion of the act it may result in emotional disturbances and may, in susceptible individuals, even interfere with the establishment of subsequent normal sexual relations. Sexual activity is not essential to the health or well-being of individuals of either sex; celibacy imposes upon those inexperienced in sexual matters no handicap except the display of the admirable quality of self-restraint. Early sexual experience is not essential for the later development of normal psychological conditioning for sexual activity. Habitual masturbation and "petting" definitely condition in the wrong directions.

Clandestine sexual activity, viewed as it is with moral opprobrium, may from a sense of guilt, the feeling of conflict with established principles of self-conduct, induce detrimental psychological effects. No physiological function is more deeply influenced by its psychological surroundings than that of sex, and none is more surrounded by social conventions. The detrimental convention is not that intended to

restrain sexual activity before marriage, but instead that which tends to keep a knowledge of the physiology of normal sexual functions from young men and women. Full knowledge of these matters solves for them many of the problems that worry them seriously; it assists them in avoiding detrimental habits; it is a prerequisite to marriage and parenthood. Such information cannot be withheld until marriage is imminent and then imparted with full success. By that time views often based upon erroneous information have already become established, and too often harmful sexual habits have become fully developed.

Internal Secretions of the Testes.

The testes and ovaries are the primary organs of sex; they are the essential structures common to the reproductive systems of all organisms that have sexual multiplication. The organs used for the transfer or reception of the sex cells, or for the development of the fertilized egg—the vas deferens, seminal vesicles, uterus, external genitalia, etc.—differ greatly in different animals; they are known as the accessory organs of sex. In addition to these there are in many animals, including man, other physical differences—and psychological also—which, while taking no direct part in reproduction, nevertheless indicate sexual maturity and serve to distinguish the two sexes. These are called secondary sexual characteristics. The enlargement of the larynx with deepening of the voice in the male at puberty is a secondary sexual characteristic, as is also the enlargement of the breasts in the female and the deposition of fat on the limbs which gives them a rounded contour. The hair which appears in the pubic regions of both sexes is a secondary sexual characteristic, as is also the beard of the male.

Both the development of the accessory organs of reproduction and the appearance of the secondary sexual characteristics are under the control of internal secretions liberated by the testes and the ovaries. If the sex glands are removed before puberty the accessory sexual organs do not develop, but remain small as in the young child; the secondary sexual characteristics fail to appear. The castrated boy retains his high-pitched voice, and fails to grow hair on his face or in the pubic region, although the hair on the head becomes luxuriant as in the female. He tends also to develop a rounded contour somewhat like the female and to grow tall, with disproportionately long arms and legs. The tallness results from delay in the ossification of the epiphyses of the bones.

The disturbance in bone growth indicates the connection between the testes and the pituitary gland mentioned above (see page 409); conversely, disturbances in the pituitary gland may have an influence upon the internal secretions from the testes, diminishing their action and so causing delayed or incomplete development of the accessory organs of sex. Removal of the ovaries before puberty causes the girl to become mannish in build; her accessory organs of sex fail to develop to maturity, her breasts do not enlarge and she does not menstruate.

Castration of a male after puberty does not result in a regression in the already developed accessory organs or in the secondary sexual characteristics. Sexual desire and ability to perform the sexual act may or may not be lost; desire when once developed is not entirely dependent upon the secretions from the sex glands. In women who have never had sexual experience, desire does not develop after removal of the ovaries, but if sexual habits have been formed they may continue unchanged as they do normally after the menopause when the ovaries cease to function. The changes produced by removal of the ovaries from a woman after puberty are essentially those which follow the menopause: menstruation ceases, the uterus and breasts slowly decrease in size and there is a tendency to gain weight from the general deposition of fat. In the female the internal secretions of the ovary and also the pituitary gland exercise a controlling influence over menstruation and many of the changes occurring during and following pregnancy.

The influence of the sex glands upon the development of the accessory organs of sex and upon the secondary sexual characteristics is exercised wholly through internal secretions and not through any nervous connections. This fact may be demonstrated by transplantation of the glands. If the testicles are removed from the scrotum and inserted in the flesh of some other part of the body they may survive and, without their previous nervous connections, continue to form their internal secretions. The accessory organs and secondary characteristics then develop normally. The fact that such transplantation can be effected not only with the individual's own sex glands, but occasionally with those from another, has given a certain scientific support to the ancient belief in the possibilities of so-called rejuvenation. The idea has long been held, but is even now sustained by little factual support, that the secretions from the testes were highly important for the maintenance of vigor and the prevention of old age. Many years ago the physiologist, Brown-Séquard, attempted to produce a rejuvena-

tion by swallowing testicular extract; in recent times the attempt has been made with testicular transplants—the Voronoff operation—and still more recently the vas deferens has been tied off—the Steinach procedure—under the belief that shutting off this passage would slow the formation of spermatozoa and increase the formation of the internal secretions. There is no sound scientific evidence that any of these procedures have any effect other than that which comes from suggestion and encouragement. Indeed, it has never been demonstrated that the testicular internal secretion has any influence toward increasing vigor or delaying old age. Eunuchs do not age prematurely. Women in whom the sexual secretions cease at the menopause have a longer life expectancy than men, and many women find the most vigorous period of their lives to be the years after fifty.

The Female Reproductive System.

The female reproductive system consists of the ovaries in which the ova are formed; a cavity, the vagina, for receiving the spermatozoa from the male and conveying them to the ovum; and a chamber, the uterus, in which the fertilized ovum is retained and nourished until it has developed into a child.

The Ovaries.

The ovaries are of the size and shape of large almonds. They are suspended within the abdominal cavity by a ligament attached to the uterus. The position of the right ovary, as judged from the anterior surface of the abdomen, is close to the appendix; the left ovary is correspondingly placed on the opposite side. The ovaries are analogous to the testicles of the male. In contrast to the vast number of spermatozoa produced, the ovaries develop only about 400 mature ova during an entire lifetime, that is, one ovum for each lunar month from the thirteenth to the forty-seventh year; they are capable of developing many times this number, but only this many are matured under the control of internal secretions. A small elevation resembling a blister appears on the surface of the human ovary as each ovum matures. The ovum is suspended in the fluid of this blister, and when the covering ruptures the ovum is discharged into the abdominal cavity.

The ovum, like the spermatozoon, contains only one-half the number of chromosomes characteristic of the human cell. This mass of chromatin is surrounded by a layer of nutrient material, the ovum thus formed being a sphere about 0.2 mm. (0.01 inch) in diameter.

A much greater supply of nutrient material surrounds the chromatin in the ova of animals which do not bear their young. The chromatin in the egg of the hen is no larger in size than that in the human egg; the greater bulk of the egg is made up of food necessary to sustain the developing embryo until the chick breaks from the shell.

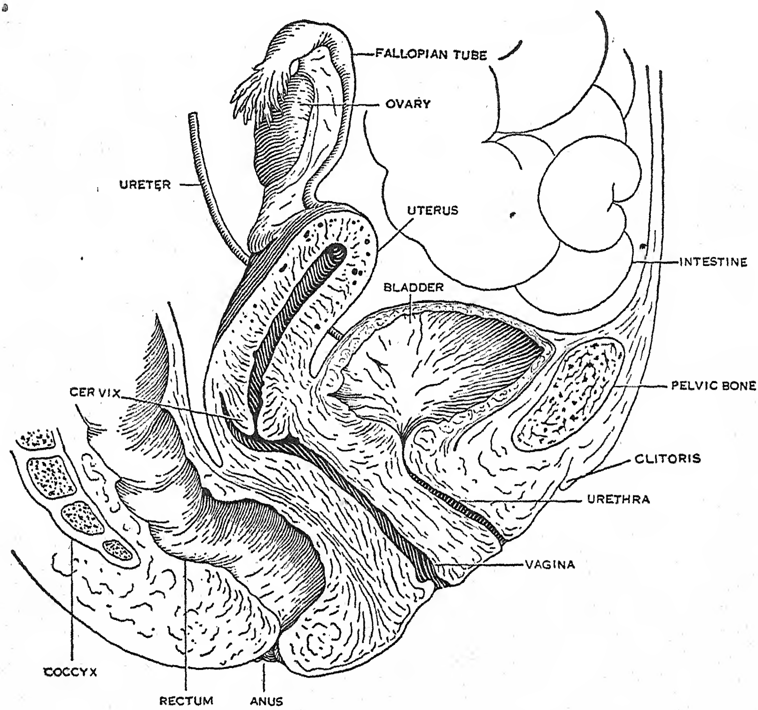


Figure 81. Schema of Female Reproductive System.

Fallopian Tubes.

The ovum discharged into the abdominal cavity passes into one or the other of the two Fallopian tubes. These tubes are analogous to the vas deferens of the male, for they are passages through which the sex cells are conveyed. The Fallopian tubes extend laterally from the upper corners of the uterus; the expanded outer end of each tube is cupped directly over one of the ovaries, the lower ends open into the uterus.

The inner surface of the tubes is lined with mucous membrane which is covered with the minute hair-like projections called cilia. The

mucous membrane of the upper respiratory tract is similarly equipped with cilia which, by their waving motion, carry dust particles out of the respiratory tract (see page 223). In like manner the cilia of the Fallopian tubes create a current toward the cavity of the uterus which draws the ovum discharged from the ovary into the tube, and propels it toward the uterus. If spermatozoa are present in the Fallopian tubes, one of them may unite with the ovum during its passage. The fertilized ovum then passes to the uterus, where it remains for the completion of its development. If spermatozoa are not present, the ovum continues its passage into the uterus without being fertilized, and is carried from the body with the next menstrual discharge.

The Vagina.

The vagina forms the cavity for the reception of the semen and the spermatozoa contained in it. It is a tubular structure opening at the surface of the body and extending inward to the uterus. The external opening is situated between the urethral outlet and the anus in a position similar to that occupied by the scrotum of the male. The vagina lies in the space between the bladder and the rectum. Folds of flesh called labia, arising from each side of the vaginal entrance, cover it and also the opening of the urethra. In women who have not borne children the entrance of the vagina is partially occluded by an irregular membrane known as the hymen. The hymen varies greatly in different individuals; in extreme cases the membrane completely closes the vaginal entrance and must be lanced to permit the establishment of the menstrual flow; in other cases it is merely a small fringe attached to the sides of the vagina. The hymen may be stretched or torn by coition, but the diversity of its normal structure often precludes the possibility of using it as a test of virginity.

On each side of the vagina, near its entrance, there are glands which are somewhat analogous to the prostate gland in the male. The secretion of these glands serves to moisten the vagina, but it has no function directly connected with the process of fertilization.

The Uterus.

The uterus, or womb, is a contracted muscular bulb. It is shaped like a pear and is held with the large end uppermost. The tapering lower end, or cervix, as it is called, projects a short distance into the inner end of the vagina. The Fallopian tubes extend from the sides of the upper part of the uterus. A small canal passes from the cavity of

the uterus through the cervix and opens into the vagina. The Fallopian tubes, the cavity of the uterus, the canal of the cervix, and the vagina form a continuous passage extending from the ovaries to the surface of the body. The size of the uterus is variable. In women who have not borne children it measures 5.5 to 8.0 cm. (2 to 3 inches) in length and 3.5 to 4.0 cm. (less than 2 inches) in breadth at its widest point. In women who have borne children the uterus is somewhat larger. The cavity of the uterus is merely a cleft, but during pregnancy it is distended to hold the developing fetus, its attachments and the fluid in which it floats; at this time the walls of the uterus are stretched thin.

The uterus lies between the bladder and rectum except during pregnancy, when the upper surface rises far above this level. It is not fixed rigidly in place, but is suspended from ligaments. Normally the upper end of the uterus tips forward and rests upon the bladder. Occasionally the uterus is displaced from its normal position and bends backward, or to one side, or even descends for some distance into the vagina. These displacements are sometimes the cause of sterility. They may also give rise to disturbances from pressure upon the bladder or rectum or from the pull upon the ligaments. They may interfere with menstruation and render it painful. Although displacements may occur in women who have never borne children, they arise more often during the first two months following the bearing of a child. The uterus at this time is large, its muscle flabby, and the ligaments are stretched and relaxed.

Menstruation.

The periodic discharge of blood and mucus from the uterus is known as menstruation. The commencement of menstruation marks the attainment of sexual maturity or puberty in the female; the average age is about thirteen. At first the periods may be at irregular intervals, but when once fully established menstruation continues at intervals usually of 28 days. It is not absolutely regular and periods of 21 to 35 are within the normal range. Premonitory symptoms such as backache, tiredness, irritability, loss of appetite, headache and enlargement and tenderness of the breasts commonly precede each menstrual period; in some cases the flow is accompanied by severe pain. The discharge ordinarily continues for from three to five days; some four to six ounces of blood are lost. Menstrual blood normally does not coagulate.

The periods of menstruation continue, except during pregnancy and usually during lactation, until the menopause. The average age for the

cessation of menstruation is forty-seven to forty-eight years, although occasionally it may be as early as the thirties or as late as the sixties. The cessation is sometimes abrupt but more often gradual; periods are missed with increasing intervals until finally no more occur. Menopause in some women may be approached and passed without any symptoms except the stopping of the periods. Usually, however, it is associated with physiological and psychological disturbances which may be mild or severe. Commonly the menstrual flow becomes more profuse as menopause approaches. The most annoying physical symptoms, however, come mainly from disturbance in the control of the blood vessels of the skin. There are "hot flashes"; the vessels of the chest, neck and face dilate and a wave of heat sweeps across these regions. There may also be dizziness, headache and insomnia. Sometimes these symptoms can be partially relieved by the administration of sex hormones by the physician. Some women show, during menopause, extreme nervousness and disturbances of personality which make the period for them and their families one of difficult adjustment. Often the mental instability of this period is made worse by the depressing physical evidence of approaching old age seen in the cessation of menstruation. At this time women need special consideration, patience and encouragement.

Menstruation may be suppressed during severe illness, exhaustion from hard work, grief or worry, even the worry arising from fear of pregnancy. Chilling the body during the time of menstruation may in some cases stop the flow or render it painful and irregular for some time afterward. The menstrual flow is usually greater in warm weather than in cold. Tropical climates induce such excessive and prolonged menstruation in some white women that they become anemic.

Many women suffer severe pains during menstruation. Formerly it was believed that rest was desirable during this time to obviate pain, but this idea is now largely being given up and women are advised to continue their normal activity. Some, however, find this impossible and are kept from their employment because of the discomfort. The pain may arise from malposition of the uterus, and in such cases cramps usually occur at the beginning of menstruation but cease as the period progresses. Often no physical abnormality can be found to account for painful menstruation. Pain may be brought on by fatigue and overwork; thus school teachers and college girls may experience little pain in menstruation during the summer and fall, but with the strain of the school year the periods become progressively more painful.

Pain under these conditions is less apt to occur as intermittent cramps than as persistent discomfort.

When menstruation is painful it is a handicap to the woman in employment. In extreme cases she may be forced to remain in bed for a day at the beginning of each period. With the proper care the pains can often be relieved. Some shops and factories have found it expedient to give their female employees treatment at the plant rather than to allow time off for difficult menstruation. The woman suffering from menstrual pains reports to a nurse who has her lie on a couch, loosens her clothing, and administers a warm drink and a sedative. After resting with a hot water bottle on her abdomen for twenty min-

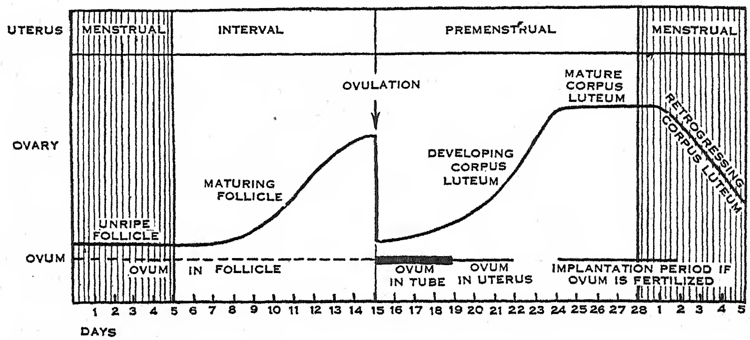


Figure 82. Relationship of Ovulation, Fertilization, and Impregnation to the Menstrual Cycle.

utes to a half hour, the woman is usually relieved to an extent sufficient to allow her to return to work.

Menstruation, used here to signify the menstrual discharge, is only one phase of a much longer process known as the menstrual cycle. Approximately five days before the appearance of the discharge the mucous membrane of the uterus becomes congested and swollen. When the process reaches its maximum the surface bleeds and the menstrual flow is produced. In the week following menstruation the congestion diminishes and finally disappears; any mucous membrane which has been destroyed then grows anew. During the twelve days remaining in the cycle of twenty-eight, the uterus is in a state of rest.

Menstruation is normally associated with the discharge of an ovum from the ovaries, ovulation, and depends for its occurrence upon the internal secretion from the ovaries. When the ovaries are removed menstruation ceases, but it is reestablished if the ovaries are successfully

grafted into some tissue of the body. It is believed that the periodicity of the menstrual changes is controlled, not by the ovary alone, but also by the pituitary gland. The ovary secretes a hormone known as oestrin or theelin. When the ovum is discharged, the spot from which it erupts develops a glandular structure known as the corpus luteum; the corpus luteum secretes a hormone known as progestine. The thickening of the mucous membrane of the uterus occurring before menstruation is due largely to the progestine. This hormone does not cause the bleeding. If the concentration of theelin in the blood is decreased, bleeding occurs whether or not the preliminary thickening has taken place. The decrease in the concentration of theelin which precipitates the menstrual flow is believed to be caused by a hormone discharged from the pituitary gland.

The normal sequence of events in ovary and uterus during the menstrual cycle is as follows: Commencing with the menstrual period, an ovum in one or the other (sometimes both) of the ovaries undergoes a series of changes preparatory to its discharge. In the small blister or follicle formed on the surface of the ovary the egg completes its division and matures. This maturity is reached on about the thirteenth to fifteenth day following the beginning of the previous menstrual flow. The egg is discharged into the abdominal cavity. Ovulation thus on the average occurs midway between two menstrual periods; there may, however, be considerable individual variation in this time relation. The corpus luteum formed on the site of the discharged ovum secretes progestine which in turn causes the lining of the uterus to thicken. If the ovum is fertilized, the corpus luteum persists and grows larger; menstruation does not then occur at the time at which the next period would be due, but, instead, pregnancy develops as described later. If the ovum is not fertilized it is carried into the uterus and eventually discharged. In this case, some fourteen days after ovulation the theelin in the blood diminishes in amount and the menstrual flow occurs. From this sequence of events it appears that the uterus reacts each month as if fertilization of the ovum was to occur and begins the changes incident to the implantation of the ovum on the mucous membrane of the uterus. If fertilization does not take place these changes are brought to an end in the discharge of the accumulated material and repair of the mucous membrane. According to this view, menstruation occurs because conception has not taken place.

Menstruation is not essential to impregnation. Many women have become pregnant before they started to menstruate, or during the time

when they were nursing a child and had ceased to menstruate for that reason, or even after the menopause. In one instance recorded in the literature a woman, who was married before menstruation had commenced, did not menstruate until she was nearly forty, for during this entire time she was either pregnant or nursing a child.

Migration of the Spermatozoa and Ova.

The spermatozoa are deposited in the vagina, usually near the opening of the cervix of the uterus. They travel from this point through the uterus and up the Fallopian tubes by means of their own motility. The spermatozoa are guided in this course by the opposing current on the surface of the mucous membrane of the uterus and tubes. The cilia on these surfaces create a current which propels immotile particles, such as the ovum, toward the cervix of the uterus. The spermatozoa are so constituted that they swim against the current and are thus guided by it.

The rate of movement of the spermatozoa is normally from 1.5 to 2.0 millimeters per minute. Consequently the tubes are reached within a few hours, but probably only a comparatively small number of spermatozoa gain this point. Large numbers die, probably from exhaustion, from the action of the unfavorable vaginal secretions, and possibly as the result of the somewhat higher temperature of the uterine cavity as compared to that of the testicle.

The ovum discharged from the ovary is drawn, as described, into the Fallopian tubes by the current created on the moist surface by the movement of the cilia in the tubes. It is carried slowly through the tubes toward which the spermatozoa migrate. It is estimated that the ovum may remain alive for two weeks, but it is passed through the tube and discharged into the uterus in about one week following ovulation. Usually fertilization of the egg takes place while the ovum is in the tube and most commonly when it is in the outer portion. The spermatozoa are believed to live only three or four days after reaching the vagina, uterus and tubes.

In the process of fertilization a single spermatozoon penetrates the ovum; in so doing it stimulates the ovum to form a membrane over its surface which prevents the entrance of additional spermatozoa. When fertilization takes place the addition of the spermatozoon to the ovum restores the full complement of chromosome material, half derived from each parent. Cell division and growth are initiated by this restoration. The growing mass of cells is carried slowly toward the

uterus by the cilia of the mucous membrane lining the Fallopian tubes. During this time the membrane of the uterus becomes thickened and congested in preparation for the reception of the ovum. When the developing ovum reaches the uterus it secretes a digestive fluid which erodes a minute opening in the mucous membrane into which the ovum enters. The mucous membrane then closes over the ovum.

Development of the Ovum.

The microscopic mass of undifferentiated cells, now parasitic upon the mother, slowly develops into the fully formed infant. As the first step in this development, fluid is formed in the center of the minute mass, until the cells constitute a shell about the collection of fluid. Next, the three fundamental tissues of the body are differentiated as three layers of cells in the shell. The inner layer of cells is called the endoderm, the middle layer the mesoderm, and the outer layer the ectoderm. Each is the progenitor of a group of tissues in the human body; each retains throughout life much the same position as that which it occupied in its initial development. The covering of ectoderm forms the skin, hair, and nails. The endoderm forms the lining of the alimentary tract and the glands which extend from it. The middle layer, or mesoderm, forms the tissues and structures which lie between the outer and inner layer—the bones, muscles, tendons, and the circulatory system. The nervous system constitutes an exception to the original distribution of the tissues, for it arises from the ectoderm just as the skin does. The primitive nervous system starts as a groove on the surface, but the sides of this groove rise and fold over, thus inclosing a part of the ectoderm within the mesoderm. This buried column of cells continues as the brain and spinal cord, and its offshoots become the nerves.

On the side of the ovum which is buried deepest in the wall of the uterus, the cells multiply more rapidly than do the others; an inner mass is thus formed which projects a little way into the fluid filling the ovum at this stage. A space filled with fluid forms within the center of this mass. As the opening increases in size it pushes its way through the middle layer of the mesoderm, until finally it has nearly completed the circuit of the inside of the ovum. What remains of the inner mass of cells is thus left hanging within this space and is attached to the inner wall of the shell by a stalk. The mass of cells thus suspended is known as the embryo. Ultimately it grows into the child. The stalk which forms the attachment to the wall becomes the umbilical cord;

and the covering of the space filled with fluid forms the membrane within which the child is developed. At birth this sac is ruptured, its fluid is discharged, and the child passes through the rent in the wall.

Formation of the Cord and Placenta.

The nourishment for the growth of the ovum and its embryo is derived from the mother. Small projections extend out from the walls of the ovum and burrow into the tissue of the uterus. The tips of these projections erode the blood vessels and blood escapes into little pools in the muscular wall of the uterus. The tips of the processes dip into this blood and absorb from it food and return wastes. At the end of the first month after its implantation, the ovum, which by this time has reached a diameter of nearly two inches, is completely covered with these processes which appear like moss.

When the blood and blood vessels form in the embryo, the vessels extend out along the stalk by which it is attached to the inner wall of the ovum. They continue out into the processes which have burrowed into the vessels in the wall of the uterus. The blood vessels of the developing child are now brought close to those of the mother. There is a free and active diffusion of dissolved food and waste through the membrane between the blood of the child and that of the mother. These two blood streams are always separated by the walls of the child's vessels; the child's blood and the mother's blood never mix.

As the ovum grows it expands into the cavity of the uterus. The inner wall of the uterus which has closed over the implanted ovum is stretched and becomes thin; in consequence its supply of circulating blood is diminished. The projections on the surface of the ovum gradually shrink and finally disappear over this area, but they remain in the part most deeply buried in the uterus, which in the ovum corresponds to the region of the stalk holding the embryo. The fleshy growth formed by these remaining projections and their blood vessels is known as the placenta. The stalk holding the blood vessels extending to the embryo, or, as it is called later in the development, the umbilical cord, is attached to the center of the placenta.

The placenta forms at whatever point in the uterus the ovum happens to implant. Usually this implantation occurs in the upper part of the uterus. Occasionally it takes place in the lower part, and the placenta may then in its growth cover the opening of the cervix. This condition of "placenta previa" may lead to serious hemorrhage during, or even before, the birth of the child. Normally the placenta remains attached

to the wall of the uterus until after the child is born. A continuance of the uterine contractions producing what are termed afterpains results in the separation of the placenta from the walls of the uterus. The placenta, together with the ruptured membranes and cord, is then expelled from the uterus, forming the "afterbirth."

Occasionally the ovum is arrested in its passage to the uterus and implants in the Fallopian tube; but a tubal pregnancy cannot develop to full term. Usually the ovum ruptures either into the tube or through its outer wall into the abdominal cavity. Severe cramp-like pains and dangerous hemorrhage result, necessitating a surgical operation.

Development of the Embryo and Fetus.

During the first two weeks of pregnancy the entire product of conception is known as the ovum. Between the third and fifth weeks the various organs are developed in the mass suspended from the stalk; to it the term embryo is then applied. At this stage the human embryo is closely similar in appearance to that of all other animals. By the end of the fifth week, however, the head has enlarged considerably because of the development of the brain, and has some resemblance to the human form. The term fetus is then applied to what was previously called the embryo.

By the end of the second lunar month the fetus has attained a length of 2.5 centimeters (1 inch). During the third month particles of calcium begin to appear in the masses of mesoderm in the structures which are subsequently to become bones. At the end of this month the entire product of conception is about 4 inches in diameter, and the fetus measures 7.5 centimeters (3 inches) in length. By the end of the fourth month the fetus is 17 centimeters (7 inches) long and weighs 120 grams (¼ pound). At this time sexual differentiation is well advanced. During the fifth month the skin becomes less transparent and is covered all over with a downy hair. During the sixth month the fetus attains a length of 25 to 35 centimeters (10 to 14 inches). If born during this period, it will attempt to breathe and move its limbs; but it dies in a short time. During the seventh month the sebaceous glands about the hairs secrete a white fatty substance which covers the skin, protecting it from the prolonged immersion in the amniotic fluid. The membrane which covers the eyes disappears during the seventh month. A fetus born at this time normally weighs 2300 grams (5½ pounds). It moves its limbs and cries, but as a rule it cannot be kept alive even with the most expert care. It is popularly believed that a child has a

better chance of living if born at the end of the seventh month than at the end of the eighth. This erroneous idea is a remnant of the old Hippocratic doctrine. The more developed the child is, the greater are its chances for life. At the end of the tenth month, 280 days, the fetus is fully developed and ready to appear as the newborn child.

The Child at Birth.

At birth the child is 50 to 52 centimeters (20 to 21 inches) in length and weighs on the average 3250 grams (7¼ pounds). The downy hair has been shed, but the skin is still covered by a greasy coating. The head is usually covered with hair about an inch in length; this hair may be dark even in the children of blond parents. It is subsequently shed. The eyes of the newborn baby are bluish.

Although 3250 grams (7¼ pounds) is given as the average weight of the newborn child, this figure is variable. The weight of perfectly healthy children may range from 2300 to 5000 grams (5 to 10¾ pounds). The latter figure is rarely exceeded; nevertheless, it is not unusual to hear reports of children weighing 15, 16 and even 20 pounds at birth. The majority of these cases are apocryphal or they are based on estimates rather than accurate measurements. In the records of 30,500 deliveries in one hospital, only five children weighed more than 5000 grams (10¾ pounds). Premature babies weighing less than 1500 grams (3¼ pounds) have little chance of life, although in exceptional cases children weighing less than 2 pounds have been successfully raised.

The social conditions of the mother, and therefore her comfort and choice of diet, influence to some extent the size of the child. Heavy children occur more commonly in the well-to-do classes. It is popularly believed that the comparatively difficult labors of the women of the upper classes are due to the enervating influences of civilization and luxury, while the easy labors of colored women and immigrant classes are considered a manifestation of a closer approach to nature. The more probable explanation lies in a difference in the size of the children at birth.

Sex of the Child.

Sex is determined at the moment of fertilization of the ovum by the process described in Chapter XXII. No effort intended to modify human sex can be effective, once the union of the spermatozoon and ovum has taken place; no known measure applied to the body can

affect the probability of the union of an X-chromosome- or a Y-Chromosome-bearing spermatozoon with the ovum. Cell division in the testicle results in a precise equality in the number of male-producing and female-producing spermatozoa. According to the laws of chance, conception should result in an equal number of each sex, but in reality, there are more male conceptions than female; the ratio is approximately 120:100. The predominance of males at conception can be accounted for only by some advantage possessed by the Y-bearing spermatozoa, possibly their lighter weight, which enables them to survive better the migration through the uterus and Fallopian tubes. Numerous attempts, all eventually failures, have been made to influence or even predict the sex of the unborn child. Since there are only two possibilties, the sex can be predicted with an accuracy of 50 per cent; the successful predictions are remembered and commented upon, while the unsuccessful predictions are forgotten.

In contrast to the predominance of male conceptions, the fact remains that more girl babies are born alive than boy babies; the ratio ranges between 101 to 108 girls to 100 boys. The male is less able to survive intra-uterine life than the female. The preponderance of female births over male may be diminished by improvement in prenatal care. In this country it is estimated that some 20 per cent of fertilized ova die before they have developed into living children ready for birth; about 4 per cent of children die at birth, and another 15 per cent during the first year of life. Thus there is a loss of nearly 40 per cent of all conceptions before one year of age. Of these deaths, more are among males than females. Improvement in prenatal care and infant hygiene would reduce the present surplus of women over men.

The embryo has the rudimentary sexual organs of both sexes and up to the third week no differences can be seen in the two. At about this time, under the influence of the sex chromosomes, probably exercised through chemical action of enzymes, one or the other of the rudimentary sexual organs begins to develop; in the embryo destined to be male the testes and cord are differentiated, and in that which is to be female the ovaries begin to develop. The rudimentary organs of the opposite sex present in the bisexual phase of the embryo persist throughout life but remain undeveloped.

Multiple Pregnancy.

The uterus occasionally contains two or more embryos resulting in twins, triplets, quadruplets, quintuplets or sextuplets. Many instances

of a greater number of children at a single labor are reported in the older literature; they are purely legendary. The most remarkable of these legends is that of the Countess Hagenan, who was said to have been delivered of 365 embryos at a single labor. One hundred eighty-two of these embryos were reputed to be male, a like number female, and the remaining one a hermaphrodite. The basin in which these embryos were baptized is still shown as a relic. The legend is not without some foundation. The delivery was not of a prodigious number of embryos, but of a growth called a hydatidiform mole. These growths are rare abnormalities in which the processes which extend from the surface of the ovum into the wall of the uterus enlarge and appear like small grapes. The dilated endings might be mistaken for embryos.

Twin pregnancies occur once in 87 births, triplets once in about 7000, and quadruplets once in half a million. Only 30 authentic cases of quintuplet pregnancies have been recorded.

About three-fourths of all multiple pregnancies arise from the fertilization of two ova. Usually only one ovum separates from the ovaries at the time of ovulation, but occasionally two, or even more, ova may be cast off simultaneously. If all of these ova are fertilized and implanted in the uterus, the corresponding number of embryos develop. These embryos are distinct; each has its individual membranes and placenta. The children born may be of the same or opposite sex; except in age, they resemble each other no more than do children born separately of the same parents. Some women appear to be predisposed toward multiple ovulation, and it is not unusual for them to have twins or triplets on several occasions. In some instances the tendency to multiple pregnancy follows the female line of a family through several generations.

About one-fourth of all twin pregnancies result from the fertilization of a single ovum. In such cases it is believed that the growing mass within the ovum separates at an early stage into two parts. These parts develop independently. Twins thus formed are inclosed in one sac and are joined to a single placenta. Such twins are identical; they are both of the same sex and resemble each other much more closely than children born separately of the same parents. Moreover, the primary cleavage of the cells in the ovum may occur in such a way that one of the twins formed is the mirror image of the other. In that event the normal position of the abdominal organs is reversed in one of the twins; the liver and appendix are upon the left side of the abdomen, and the heart inclines to the right instead of the left side of the chest. Where a similar inversion is found in a person who was not born with a twin,

it is assumed that the twin formation occurred, but that the development of one of the pair was arrested at an early stage.

Monsters.

If the child in the uterus is so deformed as to interfere seriously with the development of its body it is said to be a monster. Nearly all monsters, if they survive to birth, die soon afterward. In some monsters, for reasons unknown, parts of the body fail to develop or develop excessively. In other cases the formation of monsters bears a close relation to the development of twins from a single ovum. Identical twins represent the most complete primary cleavage; but all degrees of separation occur, and probably at various stages of development. As a result, monsters appear like the Siamese twins, in whom the separation was almost complete, or as two individuals united throughout the length of their bodies, or joined pelvis to pelvis. The cleavage may also affect only a portion of the embryo, producing double-headed or triple-legged monsters, or various parasitic monsters in which small legs, arms or a trunk project from some point on the body. Finally the cleavage may involve only a small group of cells, producing an excess of parts, such as extra fingers or two spleens.

It must be borne in mind that monsters are rare; the possibility of their occurrence need arouse little fear. The overwhelming majority of children are born well developed and normal in appearance.

Superfetation.

Twins formed from separate ova do not always develop at the same rate, for the supply of nutrition may be unequal. This inequality of size has given rise to the belief that the twins are of different age and arise from ova fertilized perhaps a month or two apart. Superfetation, as this supposititious process is called, is theoretically possible; but no well-authenticated instance of the occurrence has ever been recorded. On the other hand, it is possible for twins formed from separate ova to be fertilized by different males. The two ova are liberated simultaneously, and the separate impregnations occur within a short time of each other. Superfecundation, as this is called, is of common occurrence in animals such as the cat and dog.

Prenatal Influences.

Prenatal influence or maternal impression has been the subject of much popular superstition; the term means the imparting of some

physical or mental attribute to the child as a result of mental impressions upon the mother during pregnancy. The antiquity of this belief is illustrated in the Biblical story of Jacob. As his share of the cattle he was to receive those which were ring-streaked and striped. To increase the number of these markings he exposed before the pregnant females branches upon the bark of which he cut the desired pattern. The number of ring-streaked and striped cattle born was supposed to be increased by this maternal impression.

The theory is fallacious; and yet in the latter part of the last century a law was passed in a city of the United States which forbade crippled beggars to appear on the street for fear that crippled children would result from the impression made upon pregnant women. The Siamese twins were not allowed to exhibit themselves in Paris for a similar reason. Cases interpreted as such maternal impressions are firmly believed in by many people; but all of these examples lack one essential, they are uncontrolled. The child might have developed the same birthmark, malformation or mental quirk without the exposure of its mother; the developmental abnormality may have occurred long before the mother received the impression. Furthermore, millions of mothers have been exposed to mental impressions and have nevertheless borne normal children; normal children are born to women in lands undergoing the devastations of war. Maternal impression is called in as an explanation to satisfy circumstances that occur by chance. It is a superstition, and nothing more. The mother has no more direct mental influence upon the development of the child than a hen has upon the eggs it hatches.

Prenatal influence, aside from its superstitious aspect, has a real basis. The child during its stay in the uterus is a parasite upon the mother. Although there are no direct connections of nerves or blood vessels between the mother and the child, it nevertheless derives its nourishment from her. The relation is that of the growing tree to the soil. The nature of the soil influences the growth of the tree; if the soil is fertile, growth is full, but if the soil is barren, growth is stunted and perverted. The health of the mother influences the physical development of the child. If her health is impaired, the child suffers; likewise her mental state may react upon the child, but it can do so only indirectly by its influence upon the mother's health and thus upon the nourishment of the child. Such disturbances do not result in physical and mental abnormalities; they produce stunted infants.

Lactation.

Both the male and female are provided with mammary glands, but they function only in the female, for their activity is initiated by pregnancy. They secrete milk which provides the food for the newborn during its first year of life. The mammary glands are modified sweat glands. Each breast contains a group of twenty or more separate glands, opening by independent ducts in the raised center, or nipple, of the breast. At the time of puberty the breasts of the female increase in size, but this enlargement is due to the growth of connective tissue and the deposition of fat. The glandular tissue remains rudimentary and functionless at this time. When pregnancy occurs, the mammary glands are stimulated by an internal secretion, and as a result grow larger and fill with a fluid known as colostrum. During the later months of pregnancy the secretion can be expressed from the breasts.

After the birth of the child the glands are further stimulated and a more abundant secretion is produced. For the first day or two this secretion retains the character of colostrum, but on the third or fourth day true milk is formed. Emptying the glands by milking prolongs their secretory activity. When the ducts of the glands are filled with milk, secretion is stopped, but it is reestablished by emptying the glands. If the ducts are not emptied by milking, the secretion is suppressed within a few days and the glands become smaller. Their activity is reestablished during a succeeding pregnancy.

The internal secretion which initiates lactation comes mainly from the pituitary gland. At birth children of both sexes have been exposed to this secretion and the baby's breasts are swollen. They yield a few drops of fluid called "witch's milk." Men suffering from disease of the pituitary gland may occasionally secrete milk, and women with acromegaly sometimes give milk for a long time after the birth of a child, in some cases as long as five years. What factors initiate the flow of secretion from the pituitary gland or cause it eventually to stop are not fully known.

Changes Accompanying Pregnancy.

The changes in the mammary glands and uterus are the two most distinctive effects of pregnancy; but in addition, the whole organism of the mother is affected both mentally and physically. The growing child is a parasite upon the mother; it supplies its wants with no consideration for the mother. The diet and care of the pregnant woman can be, and should be, regulated to meet and counteract those debilitat-

ing influences. Even under the best care the mother is occasionally unable to withstand the drain upon her resources.

In the discussion of the urinary system mention was made of nephritis arising from pregnancy. It occurs when the kidneys are already weakened and are unable to carry the additional burden of excreting the waste material arising from the child. A diseased heart may likewise be unable to meet the strain put upon the circulation. Diseases such as tuberculosis and diabetes are adversely influenced by pregnancy. The dangers in all of these conditions can be detected by medical examination before pregnancy has occurred, and the risk incurred by pregnancy decreased by proper care. There are other diseases, however, arising as a result of pregnancy, which cannot be predicted. These conditions result from poisoning by some perversion of metabolism. Eclampsia and pernicious vomiting are the two most important. Eclampsia is a severe intoxication accompanied by convulsions; it occurs in the latter part of pregnancy. In the severe form of the disease the immediate removal of the child from the uterus is necessary in order to prevent the death of the mother. The early development of eclampsia can usually be detected by an examination of the urine and measurement of the arterial pressure. For this reason there should be frequent medical examinations throughout the entire course of pregnancy.

The digestion is often seriously disturbed by pregnancy, and vomiting occurs in about one-half of all pregnant women during the second and third months. This so-called "morning sickness" involves great discomfort, but usually ceases as the pregnancy progresses. In some cases, however, the vomiting becomes of such frequency and severity that no food can be retained. The condition is then known as pernicious vomiting, and it may be necessary to empty the uterus.

Duration of Pregnancy.

The duration of pregnancy is somewhat variable. In the majority of cases labor ensues approximately 280 days (10 lunar months) after the first day of the last menstrual period, so that the pregnancy is 275 days or less. This rule is subject to many exceptions; well-developed children may be born as early as 240 days and as late as 320 days after the last menstrual period.

Childbirth.

Parturition, or labor, consists in the expulsion of the child and its attachments from the uterus. The expulsive force is exerted by the

muscles of the uterus and by those of the abdominal wall. The uterus is a muscular bulb, and its only distensible opening leads through the cervix into the vagina. To effect parturition the uterus contracts intermittently upon its contents, forcing them against the cervix until the opening is dilated; it then expels them through the vagina. The cause of the onset of labor is unknown, although many theories have been advanced in explanation. Labor is an involuntary act and cannot be controlled by the will. It proceeds normally even when all the nerves from the central nervous system to the uterus have been cut.

The contractions of the uterus are nearly always accompanied by pain, the so-called "labor pains," but the amount of suffering varies greatly in different women. At the onset of labor the pains occur at intervals of from fifteen to thirty minutes; they gradually become more frequent and eventually occur every two or three minutes. Each pain lasts about one minute. The duration of labor is variable, and a much longer time is usually required for the delivery of a woman's first child than for subsequent children. Eighteen hours is an average figure for the duration of labor for the first child, and twelve for the second; but these figures are variable and labor may last from a few minutes to a day or even longer.

A large part of the duration of labor is taken up in the dilation of the cervix. The contractions of the uterus upon the membranous sac filled with fluid cause it to bulge forward and act as a wedge in forcing open the cervix. When the cervix is dilated to a size which will permit the passage of the child's head, the membranes usually rupture and their contents are discharged. The expulsion of the child through the vagina then commences. By the combined effort of the contraction of the uterus and of the abdominal walls—the latter acting much as in defecation—the child is pushed forward into and finally expelled from the vagina. Occasionally the membranes surrounding the child do not rupture during the delivery and the child is born in a sac popularly spoken of as a "caul."

The placenta remains attached to the uterus for a short time after the delivery of the child, and the umbilical cord extends from the newborn child back into the uterus. During the first few minutes after the child is born the vessels in the cord contract and force the blood which they contain into the child. The attendant then ties a piece of tape about the cord a short distance from the abdomen of the child, and severs the cord a short distance beyond this ligature. The ligature prevents the loss of blood from the child through the vessels

in the cord. After a few days the stump of the cord separates and the remnant scars over, forming the navel. During the time it is healing the stump of the cord is an open wound and must be kept clean; otherwise it may become infected.

With the birth of the child the contractions of the uterus cease momentarily, but they are soon reestablished and the placenta is expelled. When the placenta is detached from the wall of the uterus the eroded blood vessels are exposed. The hemorrhage from them is checked by the contraction of the uterus which squeezes shut so firmly that the blood cannot escape.

The head of the newborn child is large in comparison with the rest of its body. Any passage through which the head can be forced will allow the remainder of the body to pass readily. Furthermore, the head is smooth and its sides curved so that it acts like a wedge in forcing the passage. In 96 per cent or more of all deliveries, the child is born with the crown of the head foremost. The child usually comes into the necessary head-down position in the uterus during the last month of pregnancy. Prior to that time, and after the fifth month, when movement is first felt, the child is able to change its position within the uterus, and can readily be moved about by pressure from the outside. Toward the end of pregnancy the rapidly enlarging head becomes heavier than the other parts of the body, so that it sinks downward and is held in that position by the natural adaptation of the child to the shape of the uterus. At the beginning of labor the head descends into the ring formed by the bones of the pelvis; it becomes engaged there, and the child then is in position to be expelled.

The plates of bone which form the skull of a child are not firmly knit together at their edges as they are in the skull of an adult. During birth these bones are pressed into a shape conforming to the canal through which the head passes; in some instances considerable distortion of the head results. The natural shape is gradually resumed during the first week or two after birth. The bones do not cover the entire surface of the head; an opening, the "fontanel," covered by the scalp, can be felt in front of the crown, and there is a smaller one behind the crown. The growth of the bones closes these openings before the end of the second year of life.

In 3 or 4 per cent of all deliveries the child is born with some part of the body, other than the crown of the head, foremost. The face, brow, or buttocks and legs may be the part presented first. Serious

difficulty in delivery results when the face or brow is the part foremost because of the relatively large diameter of the head in these positions. So far as the mother is concerned, breech presentation causes no marked difficulty in the labor; but the danger to the child is greatly increased. The head is larger than the buttocks, and some time is required for it to emerge, even after the buttocks have passed through. During this time the cord is compressed by the head against the side of the birth canal and the circulation to the child may be cut off. With good obstetrical practice most cases of breech, face, or brow presentation are delivered without serious damage to either the mother or the child.

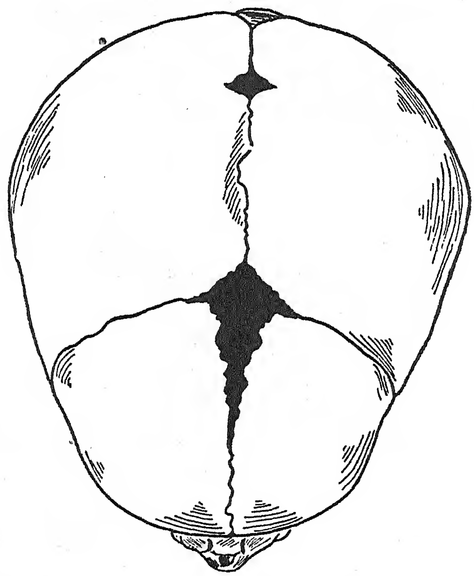


Figure 83. SKULL OF NEWBORN INFANT SHOWING FONTANELS.

Contracted Pelvis.

A small pelvis forms an obstruction to the birth more often than does any abnormal position of the child. The pelvis is formed of a ring of bones through which the weight of the body is transmitted to the legs. The sides and front of the ring are formed by the innominate or hip bones. These bones when viewed from above are crescent-shaped. They meet in front and are joined by a strong ligament. In the rear they are joined by ligaments to the sides of the sacrum.

The sacrum is part of the spinal column, but the vertebrae which form it are fused together so that it appears as one bone. The four or five vertebrae below the sacrum are small and form a tip, essentially a tail, known as the coccyx. In the outer side of each innominate bone there is a socket which forms the joint for the bones of the thigh. The side of the innominate flares outward over this socket and forms the hip. The pelvis of the female is adapted to the function of child-bearing. It is shorter, less conical, and more lightly built than the pelvis

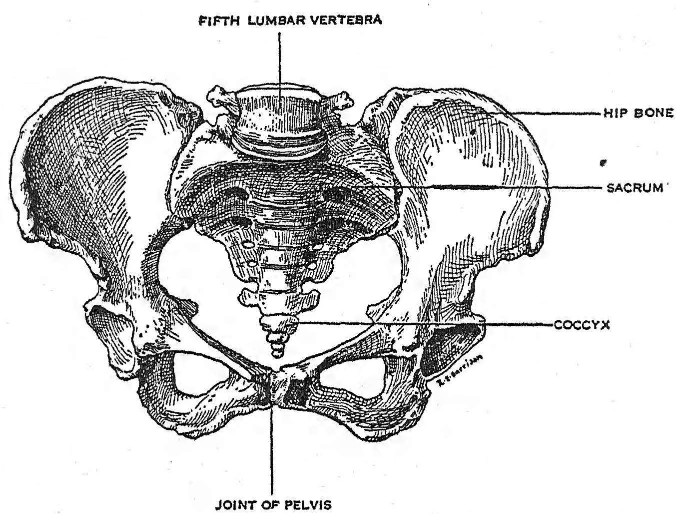


Figure 84. Bones of the Pelvis, Female.
The pelvic ring.

of the male. Furthermore, the internal diameter measured from the front to the back is greater in the female.

During birth the child must pass through the ring formed by the pelvic bones. If the size of the opening is insufficient to permit the passage of the head of the child, or permits it only with difficulty, birth in the normal manner is impossible or difficult. Fortunately, the physician is able to make measurements of the opening beforehand; he can thus detect abnormalities before labor has commenced. These measurements form a part of all proper medical care for the pregnant woman; they should be made early in the pregnancy.

A common deformity of the pelvis results from rickets. This disease is much more frequent among Negroes in America than among white women. Lack of proper development of the bones of the pelvis, or their

overdevelopment, deformity of the spine and other abnormalities also result in a small or deformed pelvis.

When it is impossible for the child to pass through the opening of the pelvis, the surgical operation of Cesarean section may be employed to make the delivery. In this operation the abdomen is opened and the child is removed through a cut made in the wall of the uterus. When the abnormality of the pelvis is determined by measurements and the operation is performed before labor has started, the effects upon the mother are no more serious than those from other abdominal operations. Moreover, the child is not injured. Cesarean section does not prevent the birth of subsequent children by means of the same procedure. Delivery by Cesarean section cannot be accomplished when the head of the child has been forced into the pelvic ring by the contractions of the uterus. If the further passage is blocked by the small size of the pelvis, little can be done except to crush the head of the child with a steel instrument and remove it. The preliminary measurements and careful medical observation of the pregnant woman have as one of their objects the avoidance of this drastic procedure.

The delivery of the child by means of forceps does not take the place of Cesarean section. Forceps are instruments designed to seize the head of the child, thus enabling the physician to assist in delivery by pulling upon the head. The use of forceps is limited to deliveries in which the pelvis is of normal size. They are used when the muscles of the uterus are weak and cannot exert the necessary expulsive force. They are likewise used to hasten the delivery when any condition endangering the life of the mother or child arises during the delivery. Obstetrical forceps intended to deliver living children were invented in the sixteenth century. Their use was kept a secret in one family of physicians and they did not come into general employment until the eighteenth century. Prior to their invention the only way of assisting labor was to insert a hand into the uterus, turn the child, and exert traction upon the feet. Infection, septicemia and death of the mother often resulted, as they did also from the use of forceps before knowledge of the need for aseptic precautions was obtained late in the nineteenth century.

Puerperal Infection.

The interior of the uterus is left raw and bleeding by the birth of the child. Normally this surface is free from bacteria and heals without infection. If bacteria of a dangerous type are introduced during

the manipulations of the delivery, severe and often fatal infection results. Puerperal infection has probably occurred as long as children have been born. In the past many theories were advanced as to its cause, the most popular being that it resulted from a retention of material in the uterus. It was only in the middle of the last century that its infectious nature was recognized. In America, Dr. Oliver Wendell Holmes was the great exponent of the contagious nature of the disease. He maintained that it could be traced to lack of proper precautions on the part of the physician and nurse. An Hungarian physician, Semmelweis, demonstrated this to be the case, but it was not until the influence of Lister's teachings and the development of bacteriology brought about a revolution in the treatment of wounds, that the infectious nature of the disease was fully established.

Formerly puerperal infection killed many women. At times it occurred in epidemics; and in some maternity hospitals the mortality rose to such a height that the population revolted against these institutions as menaces to public health. The mortality records in American cities showed that for the forty years prior to 1896, puerperal infection was assigned as the cause of death of some 13 per cent of the women dying between the ages of twenty and fifty years. During this same period similar, or even worse, conditions prevailed in every city in the world. With recognition that the procedures at delivery must be carried out with the same precautions as in a surgical operation, the mortality from puerperal infection has greatly diminished, particularly in hospitals.

A variety of bacteria may cause puerperal infection, just as they may cause the infection of other wounded surfaces. Some bacteria, particularly the streptococci, cause a more virulent type of puerperal infection than do others. Regardless of the type of organism causing the disease, its occurrence depends in nearly every case upon direct infection of the uterus through lack of cleanliness on the part of those assisting at the delivery. Cleanliness is the supreme virtue of modern hospitals and of competent physicians. Even the poorest people can obtain such service, for in all large cities maternity hospitals are operated at a low rate and many have an out-patient obstetrical service which is free. The well-to-do patient can obtain the necessary cleanliness in delivery by making the same careful choice of a physician for obstetrical procedures as she would for a major surgical operation.

Premature Birth.

The terms abortion, miscarriage and premature birth are synonymous to the extent that they signify the expulsion of the contents of the uterus prior to the normal time of labor. The term abortion is used properly when the expulsion occurs before the third or fourth month of pregnancy; miscarriage, between this time and the seventh month; and premature birth, after the seventh month. The term abortion is commonly used by the medical profession to cover both abortion and miscarriage; the laity, on the other hand, use the term miscarriage because the term abortion has in its common use come to mean criminal procedure.

It is estimated that one out of every five or six pregnancies terminates prematurely. The most common causes are inflammation or displacement of the uterus and abnormalities in the development of the fetus. After the fourth month systemic disease of the mother becomes the commonest cause. The induction of abortion by artificial means is a criminal act, except when the physician deems the procedure necessary to preserve the life or health of the mother. In this case the contents of the uterus are completely removed by surgical operation. Criminal abortion is unfortunately common; its detection is difficult. The illegality of the procedure makes it especially dangerous to the health of the woman, for the risk of punishment forces the practice into the hands of those who are ignorant of the principles of surgical cleanliness. Killing the fetus with a sharp instrument, as is the common practice, sometimes leads to fatal perforation of the uterus and often to the introduction of infection. Moreover, portions of the membranes and attachments may be retained in the uterus and cause prolonged hemorrhage and inflammation.

CHAPTER XXI

GROWTH, DEVELOPMENT AND LONGEVITY

USUALLY A CHILD CRIES AS SOON AS IT IS BORN AND, IN CRYING, RESPIRATION is established. During the life of the child in the uterus the blood from the right side of the heart does not pass through the lungs, but is short-circuited directly to the left side of the heart through an opening in the septum between the auricles (see page 139). With the first breath this opening is closed and the pulmonary circulation is established. Occasionally a child does not spontaneously start breathing when it is born; it is then necessary to employ measures essentially like those of resuscitation in order to start respiration. To this end the child's skin is irritated either by friction or by cold water, and in extreme cases the lungs are gently inflated and artificial respiration is used, sometimes combined with the inhalation of oxygen containing 10 per cent of carbon dioxide (see Chapter X). When normal breathing has been established the child is wrapped in a blanket. A drop of dilute silver nitrate solution is put in each eye; this is an important prophylaxis against purulent conjunctivitis leading to blindness (see page 402). The baby's body is then thoroughly oiled to remove the sebaceous secretion which covers it; but for the first week or two washing is carried out cautiously to prevent infections of the skin. The stump of the cord is covered with a sterile dressing and the abdomen is wrapped in a flannel band eight to ten inches wide, pinned snugly. The band is worn during the first few months. The child is dressed, place in a crib, and covered with blankets. The crib is kept in a partially darkened room. Young infants should not occupy the same bed as the mother because of the danger of overlying, the mother in her sleep rolling over upon the child and smothering it. Some crying is natural, but the fact should not be overlooked that crying arises from discomfort, and that it stops when the child is again comfortable.

Although the regulation of body temperature is imperfect at first, the clothing of the infant should be light and loose as well as warm. It should be supported from the shoulders and not from a waistband.

Elastic bands, such as garters, should not be placed on the limbs, for the soft flesh allows the elastic to sink in and impede the flow of blood. It is a common mistake to overload children, especially infants, with bed covering at night.

Development of the Nervous System.

Normal, healthy development of the nervous system depends upon quiet, rest, and freedom from excitement. The brain grows more during the first two years than during all the rest of life. It is important for proper nervous development that infants should not be played with. Stimulating them to laughter and excitement by sights, sounds or movements until they shriek with apparent delight is injurious to the still delicate and developing nervous system of the child. It is especially harmful when done just before the child is put to rest for the night. A child is not a plaything, as many adults seem to think.

During the first two or three days the normal infant sleeps almost continuously; during the first few weeks it sleeps from twenty to twenty-two hours out of the twenty-four, waking only from hunger and discomfort due to urine and feces. During the next six months the healthy infant sleeps sixteen to eighteen hours in the twenty-four; during the second year, fourteen to fifteen hours. Disturbed or irregular sleep in infants is due mainly to two causes—hunger and indigestion.

Muscular Development.

Observations on growth—that is, increase of weight—are of the utmost importance during infancy and childhood. By this means diseases are detected in their incipiency. The child should be weighed each week for the first six months, bimonthly for the rest of the year, and monthly during the second year. The normal and healthy infant shows a gain at each weighing. On the average a gain of approximately fourteen pounds is made during the first year, and six pounds during the second.

The first voluntary muscular movements are made about the third or fourth month; the infant then attempts to grasp objects placed before it. At about this time also the head can be held erect when the body is supported. The child can sit up at the seventh or eighth month. In the ninth or tenth month it makes the first attempts to pull itself up so as to bear its weight upon the feet. The first attempts

at walking are commonly made in the twelfth or thirteenth month; the average age at which children walk alone is the fourteenth or fifteenth month. There is, however, a considerable variation in the age at which children walk; sometimes marked differences are seen in different families. Rickets is the most common cause for considerable delay in walking. A child should not be restrained from standing or walking when inclined to do so. The belief that children are made bowlegged by premature standing is fallacious; children in whom the legs are markedly bowed usually have rickets, and the deformity develops regardless of standing. On the other hand, a child should not be urged to stand or walk, but such matters should be left to its own voluntary action.

The muscles of the eyes of the newborn do not coordinate until about the end of the third month. Infants cross their eyes frequently; if this habit persists it may lead to squint. It may be prevented in some cases by so placing the child's playthings and food that they must be reached for at arm's length instead of being held close to the face (see page 390). At birth infants are deaf; the deafness sometimes persists for several days. It is believed to be due to absence of air in the middle ear.

Speech.

There is a wide variation in the time at which speech develops. Girls as a rule talk from two to four months earlier than boys. Toward the end of the first year the average child begins with one or two words. By the end of the second year he is able to form sentences of two or three words. Progress from that time on is rapid. Names of persons are commonly acquired first, then names of objects, after which come verbs, and finally adverbs and adjectives. If a child of two years makes no attempt to speak, it may usually be inferred that it is mentally defective or that it is deaf.

Dentition.

The time of appearance of the teeth and also the important dietary factors influencing their development are discussed in Chapter II.

Infant Feeding.

The change in nutrition at birth is abrupt. Before birth the child derives its nourishment by diffusion from the blood of the mother; that fluid contains every essential nutriment in the most available

form. After birth the child obtains its food only through its own digestive tract; this system is as immature as is the infant as a whole. Mother's milk is normally an ideal infant food, but the composition may be affected by the mother's physical and mental state; if she becomes ill the milk may become unsuitable for the child. Proper diet for the mother, regular habits of sleep and exercise, and freedom from excitement, worry and overwork are essential to the successful nursing of the child. The capacity for nursing appears to be steadily diminishing in America. Few mothers in the well-to-do classes are able to continue satisfactorily beyond the sixth month. A similar decline, although to a less degree, is seen in the poorer classes. The decrease is more serious among the latter, for they may lack the facilities, and in some cases the intelligence, for proper artificial feeding.

In Europe, the so-called "wet nurse" is often employed instead of artificial feeding; when maternal nursing becomes impossible, another woman nurses the child. The danger of transmitting contagious diseases is the only serious objection to this procedure. In America there are practical obstacles which generally preclude wet nursing; wet nurses are recruited from the peasant class and in this country that class does not exist.

Artificial Feeding.

Any substitute for mother's milk should furnish the same constituents and in the same proportion as they exist in human milk. No food except milk, usually cow's milk, meets the requirements even approximately. Although cow's milk furnishes the required constituents, they are not in the proportion suited to the human young. Usually cow's milk must be modified before it can be used. Cow's milk contains approximately twice as much protein, and only a little more than half as much carbohydrate as human milk. The earliest milk modification was simply dilution with water to reduce the concentration of protein, and the addition of enough cane sugar to bring the carbohydrate to the proper concentration. A similar modification, usually with the substitution of milk sugar or other carbohydrate for the cane sugar, is largely used today.

Although there is no satisfactory substitute for milk, nevertheless a variety of preparations are manufactured and sold as substitutes. These compounds are condemned by authorities on infant feeding, but they are widely advertised and extensively sold. When given without the addition of milk, rickets and scurvy may follow their pro-

longed use. These foods are composed largely of carbohydrates and are lacking in fat and often in suitable protein; some even contain a large percentage of raw starch. The rich carbohydrate diet supplied by these foods often makes a child large and apparently fat. Actually the child is not fat, but contains an excess of water; this water is quickly lost and the weight correspondingly decreased, even by slight illness. The picture of the child gives an impressive appearance in advertisements; but such children are usually soft and flabby, and offer little resistance to disease.

The greatest drawback to artificial feeding is not the chemical composition of the food, for that can be suited to the needs of nutrition, but instead the forced regularity of bottle feeding. When an infant is fed on the breast it takes the amount of milk it wants and the mother has no way of judging this amount. With the bottle she can see exactly how much milk the infant has consumed. Her tendency under the dicta of nutritional experts is to feed the infant prescribed amounts at prescribed intervals as if the infant were a machine rather than a human being with all variable needs for food that human beings show. A child of even a few months of age should have the privilege of indicating how much or how little food it desires at each feeding, and in some measure the frequency of the meals. Good feeding habits that satisfy the child are not calculated solely by clock and measuring cup.

Fruit juices are an important addition to the diet during the first year. Orange or tomato juice is given daily after the third month and the amount is increased from a teaspoonful to one or two ounces by the end of the year. Iron is added to the diet, usually in the form of beef juice (not beef tea), beginning late in the first year. During the first year also the diet is gradually altered to include eggs, gruel, cereal and broth. Milk is continued, usually as unmodified but pasteurized cow's milk. Vitamin D, as in fish liver oil or, on the advice of the physician, in the synthetic form, is an important early addition to the diet for the prevention of rickets and for proper tooth development.

Bacteria in Milk.

Human milk taken directly from the breast is practically free from bacteria; the only contamination is by a relatively few cocci from the skin about the nipple. Cow's milk, when delivered to the consumer, may contain a large number of bacteria. Certain of the organ-

isms which may be present, notably tubercle bacilli, arise from the cows themselves; others are introduced during the handling of the milk. Among the latter may be the organisms of such infectious diseases as scarlet fever, diphtheria and typhoid. More often there are bacteria which do not cause specific human disease, and which arise from the dirt and dust about the stable; these bacteria when present in large numbers are believed to play a part in causing the diarrhea of infancy.

Most bacteria grow readily in milk, but keeping the milk cold inhibits their growth. The number of bacteria in any sample of milk depends upon the original contamination, the temperature at which it has been kept, and its age. The three influencing factors are illustrated by the following observation. A sample of milk was taken in a clean dairy; the sample contained at the time only 300 bacteria in each drop. It was cooled to 45° F. and kept at this temperature. After 24 hours each drop contained 400 bacteria; after 48 hours, 900, and after 72 hours, 150,000. Another sample taken in an unclean dairy contained at first 2000 bacteria per drop, and in 72 hours, 16,500,000. In still another test four samples of the same milk were kept at different temperatures for 24 hours; the bacteria in equal quantities of each sample were then estimated.

Sample	1,	kept for	24 hours	at	60° F.,	contained	134,340	bacteria
"	2	"	" 24	"	" 55° F.,	"	67,170	"
"	3	"	" 24	"	" 50° F.,	"	1,352	"
"	4	"	" 24	"	" 45° F.,	"	448	"

Pasteurization of milk (see Chapter IX) kills the organisms causing the specific infectious diseases, but does not kill all of the other bacteria in the milk. After pasteurization the milk must be kept cold to prevent their growth. Milk may be sterilized by heating it to the boiling point for five minutes. This boiling alters the composition of the milk to some extent and lowers its vitamin content. The use of such milk as the sole diet over a long period may lead to scurvy and other forms of malnutrition. Great improvement has been made in recent years in the handling and distribution of milk. In most cities the regulations covering these matters are rigidly enforced. In addition, numerous health centers distribute milk, properly modified for each infant, at a low cost and in some cases free. These centers also make frequent examinations of the infants to whom the milk is distributed, and instruct the mother in the proper care of her baby. Such institutions contribute

to the progressive decline in infant mortality which has taken place in recent years.

Periods of Growth and Development.

Several different periods are recognized in the growth and development of the body. The boundaries between the periods are not sharply defined, but are determined by the characteristics which prevail after they have become established. The main periods are:

1. Infancy: the first and second years of life.

2. Childhood: the period extending from infancy to the appearance of the first permanent teeth, or about the seventh year.

3. Boyhood or girlhood: the period extending from childhood to puberty, which usually comes at the thirteenth or fourteenth year.

4. Adolescence: the period beginning at puberty and terminating at maturity, which is about the sixteenth or seventeenth year for women, and the twenty-first year for men.

These four periods complete the growth of the body.

5. Maturity: the period extending up to the prime of life, forty-fifth to fiftieth year, or the climacteric in women. During this period men and women exercise their full physical and mental powers.

6. Senescence: the period beginning in the late forties or early fifties and characterized by a gradual diminution of the physical and mental powers. The two do not necessarily follow the same course; the mind may stay brilliant in an enfeebling body.

Senescence is a normal and invariable occurrence; senility, on the contrary, is aging caused by disease, such as the childishness of the aged which may result from sclerosis of the arteries of the cerebrum.

Rate of Growth.

Growth measured as a percentage increase in height or weight is especially rapid during the early years of life, but the greatest gross increase occurs during the period of adolescence. The average weight of a child at birth is seven to seven and one-half pounds, with reasonable extremes of five to ten pounds. During the first two or three days after birth the infant loses weight, then commences to gain, and by the seventh to fourteenth day regains its birth weight. In the first six months the weight is doubled, and by the end of a year tripled. At birth the average child measures twenty to twenty-two inches in length, and by the end of the third year has reached about half the stature it will attain at full growth.

The growing period of the female is shorter than that of the male; maturity and cessation of growth come at an earlier age and with less stature and weight. After the tenth or twelfth year the female grows more rapidly than the male of equal age, and is both taller and heavier until the sixteenth or seventeenth year, when the two sexes are again of equal weight and height. After the seventeenth year women grow comparatively little, whereas the growth of the male continues up to the twentieth or twenty-first year.

During growth the percentage increase in weight is greater than the increase in stature. This means that the body fills out as well as elongates, but less than as the cube of the height. The weight per unit of length becomes greater as maturity is approached. Thus the weight of an average boy or girl of seven, 20 kilograms, divided by the height, 11.5 decimeters, gives a value of 1.8; at fourteen years this becomes 3.0, and at maturity the average figure is 4.0. For a young adult a height-weight relation in decimeters and kilograms of 4.0 represents good proportioning of the body; 5.4, obesity; and 3.6, emaciation. These same values given in the relation of inches and pounds are 2.2, 3.0 and 1.9, respectively.

Longevity.

In human society there is always an overlapping of ages, an intermingling of the young, the mature and the old, through an age range extending from birth to, and exceeding, 100 years. Human beings do not, like fish, live in groups or schools of uniform age. Because of the differences in individual length of life there is in each decade from birth onward a diminishing proportion of the population. The numerical age structure, as it now exists in the population, is shown in Figure 85. As pointed out in Chapter XXII, these numerical relations are now changing with the increasing average length of life.

Few men attain to or exceed the age of 100 years. There are reported instances of men attaining the age of 150 or 160 years, such as Henry Jenkins and Thomas Parr of England in the seventeenth century. Such figures are certainly erroneous and are probably derived from inaccurate records in which the common names of two individuals, father and son, senior and junior, have overlapped in the village records, to be mistaken for a continuous life. The more accurate records of today show that only one individual out of 92,000 reaches the 100th year; the longest span officially recorded in the United States is 107 years.

All species of animals except the lowest show a natural span of life.

For some, like chickens, cats and dogs, it is only a few years; for others, like geese, parrots and turtles, it may approach the century mark. But all cats and dogs or geese and parrots, even under the best conditions, do not grow old and die at the same age; they show individual variations that center about an average figure for each species of animal. The fact that an occasional man, or more commonly a woman, reaches a hundred years is no indication that this figure represents the natural

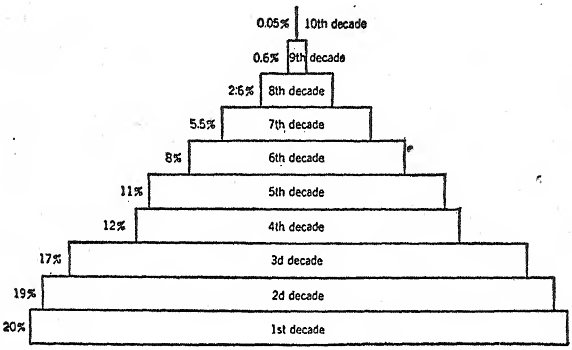


Figure 85. Numerical Age Structure of the Population.

span of life. It is an extreme; the average, when all obviously premature deaths are removed from the calculation, certainly is not greater than 70. Unquestionably the most important feature in determining the length of life of the individual is heredity.

The age at which famous men have produced their master work has been studied in the hope of finding some relation between achievement and maturity. The results obtained by W. A. N. Darland for 400 such men are given in Table XIV.

Table XIV

Age of Production of Master Work	Profession
41	Chemists and physicists
44	Inventors, poets, dramatists, playwrights
46	Novelists
47	Explorers and warriors
48	Actors and musical composers
50	Artists
51	Reformers and essayists
52	Physicians, surgeons and statesmen
54	Philosophers
56	Astronomers, mathematicians and satirists
58	Jurists and naturalists

Table XV, prepared by C. M. Cox, shows the life span of 282 eminent men born between 1450 and 1850, classified according to their major work.

TABLE XV

Profession	Average Life Span, Years	Percentage That Lived Less than 50 Years	Percentage That Lived More than 80 Years
Statesmen	70.0	4.5	30.0
Philosophers	68.4	4.5	13.5
Scientists	68.0	5.5	13.0
Poets, novelists and dramatists	67.8	2.0	12.0
Religious leaders	67.3	9.0	17.0
Essayists, historians, critics and scholars	63.7	17.5	17.5
Artists	67.8	15.5	8.0
Soldiers	67.6	18.5	7.5
Musicians	61.8	27.5	0.0
Revolutionary statesmen	51.4	44.5	0.0
Average	65.8	11.0	14.5

Peaceful statesmen here head the list in longevity, and revolutionary statesmen, for obvious reasons, are at the foot. It is not clear why famous musicians have a shorter life than soldiers. Of all the famous men listed, 14.5 per cent lived to be over 80 years of age; this figure is nearly fifteen times the expected number on the basis of the population as a whole. One may conclude either that men with the propensity for longevity are unusually active and productive or that men who are unusually active and productive tend to live long.

CHAPTER XXII

THE PRINCIPLES OF HEREDITY; CANCER

HEREDITY INCLUDES ALL THE AGENCIES WHICH, WORKING FROM THE INSIDE of the organism, control the development of the fertilized ovum into the adult. Environment includes all agencies which exercise their influence from the outside. The primary agents of heredity are within the ovum and spermatozoon; they are derived from the parents. Specifically they are believed to exist in the cells as particles or chemical units known as genes. Hence the term genetics is applied to the study of heredity.

The Mendelian Law.

The basic laws of heredity were first demonstrated experimentally in 1866 by an Austrian monk, Gregor Mendel, although the significance of his observation was not realized until 1900. Mendel planted in his garden two kinds of peas, one tall and the other dwarf. He fertilized the tall variety with the pollen from the dwarf, and the dwarf variety with the pollen from the tall. The seeds which developed were then planted. Tall peas grew from all of them. This crop was allowed to fertilize itself (the pea is normally self-pollinating) and the seeds obtained were planted. An unexpected growth appeared; there were both tall and dwarf peas, but there were three times as many tall as dwarf. When the seeds from this crop were planted, only dwarf peas grew from the seed taken from dwarf plants; but from the seeds planted from the tall peas, providing they were unselected, there grew three times as many tall as dwarf, no matter how many years the tall ones were replanted. From among the tall ones a pure tall race could, however, be developed by selecting such as produced no dwarf offspring.

Environment.

The environment in which the peas grew, the nature of the soil and the atmosphere and the amount of water, influenced the development of the plants, but only within limits maintained by hereditary endowment. It did not change the tall peas into short or the short into tall.

In human beings environmental influences, such as dietary deficiencies and infectious diseases, may influence the development of the embryo and the child, but again only within limits maintained by heredity. The environment influences the display of qualities already established by heredity. It is often erroneously assumed that children start life with precisely the same endowments, are essentially blanks to be shaped by environment, and that any differences in adults are explainable on the ground of differences in environment. Actually both heredity and environment play their respective parts. The heredity of children, even in the same family, is usually somewhat different because the parents themselves are derived from hybrid ancestry. Consequently even brothers and sisters do not start with the same hereditary endowment and will therefore develop differently even under the same environment.

The Chromosomes.

The explanation of the findings of Mendel and of the general principles of heredity has become clear in our present knowledge of reproduction. Both in animals and in plants the "germ cells"—the ovum or egg from the female and the spermatozoon from the male—contain a number of particles which, because they absorb certain dyes, are known as colored bodies or chromosomes. Every species of plant and animal has a certain unvarying number of these bodies in its cells; the human has 24 pairs. Growth of a tissue is brought about not by increase in size of cells but by increase in number. This increase is effected by division of the cells. In this division, with one exception, the chromosomes divide equally, that is, half of each chromosome goes to each half of the dividing cell. Thus each daughter cell produced by the division obtains the full number of chromosomes carrying a full complement of the heredity-bearing qualities. The exception is the cell division leading up to the formation of the ovum and spermatozoon. Here the cell divides in such a manner that each ovum and each spermatozoon carries away only one-half the number of chromosomes. Each then is literally half a cell. When the ovum and spermatozoon unite in fertilization, the full number of chromosomes is restored; but half of them—hence half the hereditary qualities—are contributed by each parent. The hereditary endowment of the offspring is thus a blend of those of the mother and the father.

The influences of inheritance are not limited to the immediate parents, but extend back to the grandparents and beyond. The germ

cells of both parents contain chromosomes derived from each of their parents (the grandparents); hence during the division some spermatozoa or ova may receive the characteristics of one, while others may receive the characteristics of another grandparent. Any quality possessed by all the grandparents will, however, be found in all the germ cells after the division of the chromosomes. So far as can be determined, this division of the chromosomes is controlled entirely by chance.

Dominant and Recessive Characteristics.

In the experiments of Mendel, the germ cells of the tall peas which he planted contained in their chromosomes a determinant for tallness. It was a so-called dominant characteristic since its peculiarity became evident whenever present, even if derived from only one parent. The seeds resulting from any combination in which this chromosome appeared grew tall peas. Therefore the seeds planted from the peas which were cross-pollinated all grew tall, for they contained half of the chromosomes from the dwarf and half the chromosomes from the tall peas. The determinant for dwarfness was recessive since it influenced growth only when the determinant for tallness was absent.

When these peas were allowed to pollinate themselves, the arrangement of the chromosomes fell into all the combinations of chance. There were four equal possibilities in this second generation. A seed might contain chromosomes derived entirely from the dwarf grandparent, and would therefore grow dwarf, or it might contain half from each grandparent in the two combinations possible, or it might have the chromosomes derived entirely from the tall ancestors. Each of the last three combinations would grow tall peas, thus explaining the ratio of one dwarf to three tall found by Mendel.

Figure 86 illustrates the Mendelian law of inheritance as exemplified in the cross-pollination of tall and dwarf peas. In this figure the black represents the dominant quality of tallness, and white the recessive or dwarf quality. Any circle which contains the black represents the seed which will grow into a tall pea. Many hereditary characteristics are neither dominant nor recessive, but are intermediate, indicating a compromise between dominant and recessive factors.

The so-called familial and therefore hereditary form of feeblemindedness (see page 365) may be used here to illustrate the operation of the Mendelian law of heredity. Feeble-mindedness is not a positive quality, but rather the condition which results when some

quality, a degree of intelligence, is lacking. Intelligence thus behaves to some extent as a dominant characteristic like the determinant of tallness in the peas in the experiments of Mendel. When the dominant quality of tallness is lacking in the seeds, dwarf peas result; when the quality of intelligence is lacking in the germ cells from which the child develops, a dwarfed mentality results.

In considering the inheritance of feeble-mindedness, or more correctly the failure to inherit a reasonable degree of intelligence, we must take into account three types of individuals: (1) The type composed of those who have received the characteristic of intelligence from both

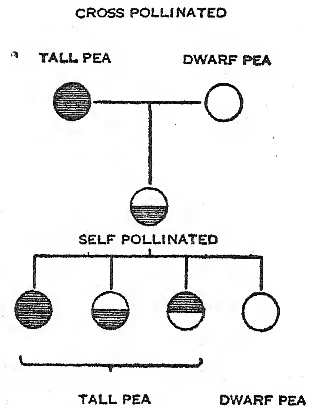
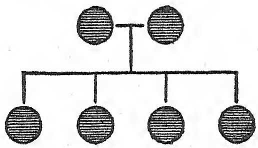


Figure 86. Mendelian Law of Inheritance Illustrated by the Cross Pollination of Tall and Dwarf Peas.

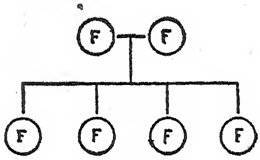
parents. Such an individual may be represented by a black circle, like the tall pea which breeds true in the diagram of the Mendelian law. (2) The type of individual who has not received the dominant of intelligence from either parent and who is therefore feeble-minded. He is represented by the white circle. And (3) the type of individual who has received the dominant of intelligence from only one parent and who is represented by a circle half black and half white. He is not himself feeble-minded, for he has received the dominant quality; but he may have children who are.

Parents of these three types may breed in six possible combinations. The proportion of feeble-minded offspring may be foretold by the Mendelian law. This does not mean, however, that the laws of chance will operate with exactitude in the limited number of offspring which result from a single human mating. The nearly exact proportion will



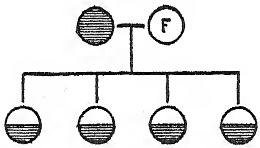
Mating of individuals who have received the dominant quality of intelligence from both parents, i.e., class 1.

All offspring normal-minded; class 1.



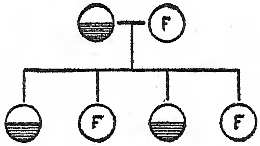
Mating of feeble-minded individuals who have not received the dominant quality of intelligence from either parent, i.e., class 2.

All offspring feeble-minded; class 2.



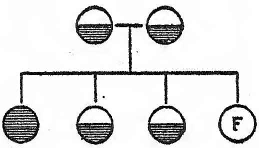
Mating of individuals from class 1 and 2.

All offspring normal-minded but belonging to class 3.



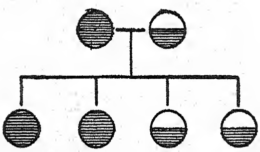
Mating of individuals from class 3 and 2.

50 per cent of offspring feeble-minded and 50 per cent normal but of class 3.



Mating of individuals from class 3.

25 per cent of offspring feeble-minded. 75 per cent normal. But of these normals 66 per cent are in class 3. Only 25 per cent of all the offspring in class 1.



Mating of individuals from class 1 and 3.

All the offspring normal; 50 per cent in class 1 and 50 per cent in class 3.

Figure 87. Inheritance of Feeble-mindedness According to the Mendelian Law.

appear only when the children of many similar matings are considered collectively. Figure 87 shows the proportion of feeble-minded offspring from all the possible matings of parents of the three types.

Transmission of Color.

The color of the eyes is determined by the Mendelian law of inheritance. The pigmentation of the iris ranges from dark brown to a complete absence of brown; the iris lacking any brown is pure blue. Brown is inherited as a dominant characteristic and always shows when transmitted in the chromosomes. Thus the children of two parents with pure blue eyes also have blue eyes; but if one parent has blue eyes and the other pure brown (deep brown from two dominants) the children invariably have brown eyes, usually in shades of light brown and hazel. When parents have this type of brown eye coloring (i.e., dominant brown from only one parent and recessive from the other), the children will show the whole range of eye color from dark brown to blue.

Sometimes the inheritance of a trait follows a more complex law than the simple one of a single dominant and recessive as described here. The trait may depend upon the presence of two dominants. Such apparently is the case in the skin pigmentation of the Negro; two dominants from both parents are essential for full black color; less leads to lighter shades of color. The offspring from the mating of mulattoes—half black—may be lighter or darker than either parent, but probably no darker than the sum total of the darkness of both parents, for black is here the dominant characteristic. Thus if *a* and *b* represent the recessive character of whiteness, and *A* and *B* the two dominants for blackness, the mating of a white and a full black, *aabb* and *AABB*, would result in two recessives and two dominants in any of the various combinations permitted, one of which would be *AaBb*. The offspring from mulattoes with this genetic composition would, if in sufficient numbers to permit the full operation of chance, show the following combinations in the proportions indicated:

1	AABB	full black
2	BBAa	¾ black
2	BbAA	
4	BbAa	½ black, mulatto
1	BBaa	
2	bbAA	
1	Bbaa	¼ black, quadroon
2	bbAa	
1	bbaa	white in color

For some qualities, such as stature, inheritance is even more complicated; it depends upon several genes and is incapable of simple Mendelian analysis. If both parents are exceptionally tall the children will be tall since they lack a gene which brings about the early cessation of growth. If both parents are short their germ cells may or may not carry the growth-suppressing gene; the children may be tall or short or of medium height.

Determination of Sex.

Sex is determined when the ovum is fertilized (see page 506) and is subject to the Mendelian law of inheritance. In this case the actual genetic difference in the male and female cell can be seen under the microscope. In human cells there are 24 paired chromosomes—a total of 48 single chromosomes. The first 23 pairs are designated successively by the letters of the alphabet from A to W inclusive. Each member of these pairs is alike so that when they are divided in the formation of the ovum or sperm, which contains 24 single chromosomes, no visible difference exists. The 24th pair, however, may show differences. In the female the pair is made up of two equal single chromosomes, each designated as X. In the formation of the ova each receives one single X-chromosome. In the male the pair is made up of a large chromosome like the X of the female and so designated, and a small one called Y. In the formation of the spermatozoon the division of the XY chromosome gives X to half of all the spermatozoa and Y to the other half. There are thus two types of spermatozoa. The union of an X-chromosome-bearing spermatozoon with an ovum results in the presence of two X-chromosomes; this is the female complement, and the child developed from this fertilization is female. The union of a Y-bearing spermatozoon with an ovum results in the presence of an XY pairing of the chromosomes; this is the male complement, and the child developed from this fertilization is male.

Sex-linked Traits.

The X-chromosome carries its full supply of genes and all are linked with sex, that is, carried in chromosomes that also carry the genes which determine sex. The Y-chromosome, which is always derived from the father, contains few or no sex-linked genes. Sons obtain their sex-linked characteristics only from their mother (the X-chromosome); consequently boys inherit less from their fathers than from their

mothers. Girls inherit equally from both since they obtain an X-chromosome from each.

This linkage of genetic qualities with sex chromosomes is highly important in the transmission of certain diseases. If one X-chromosome

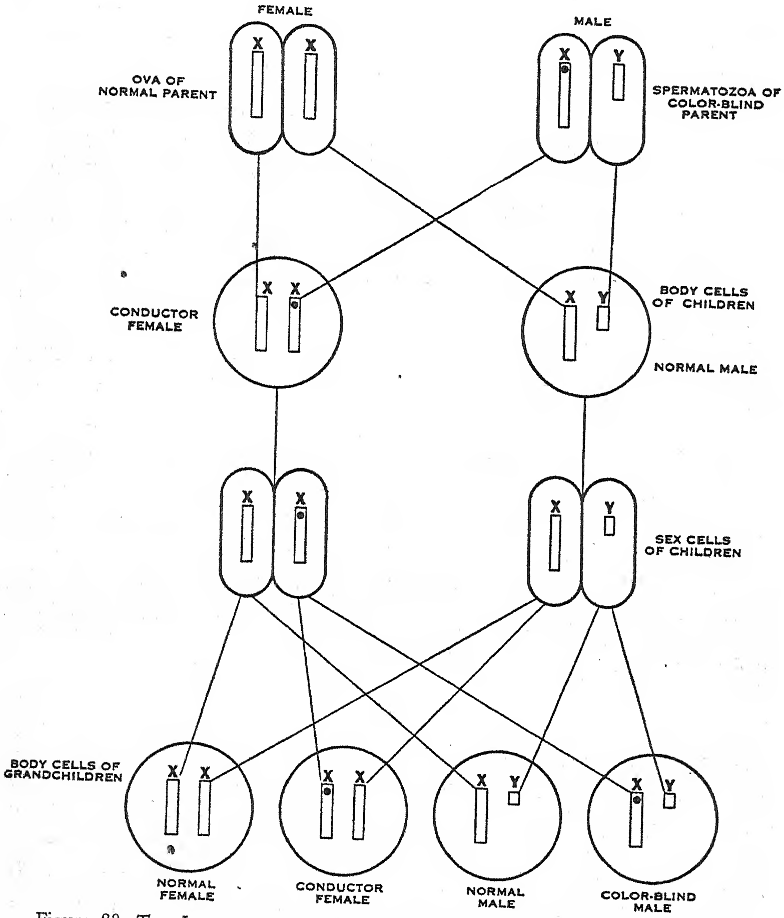


Figure 88. THE INHERITANCE OF THE SEX-LINKED TRAIT OF COLOR BLINDNESS.

is defective in its genetic qualities the deficiency is compensated for in the female by the X-chromosome derived from the other parent. The disturbance due to genetic deficiency does not then appear. In the male the Y-chromosome with its normal deficiency of genetic qualities cannot thus compensate for a defective X-chromosome and the dis-

turbance appears. Such traits as color blindness, hemophilia, and defects in the optic nerve are transmitted in this manner.

Figure 88 shows the transmission of the sex-linked trait of color blindness. It will be seen from this diagram that none of the sons receive the defective X-chromosome from the father, but all the daughters do. The X-chromosome without defect that comes from the mother compensates for the deficiency in the daughters and they are not color-blind. Their ova, however, are of two sorts, those with and those without defective X-chromosomes. The former give rise to color blindness in half the sons. The number of color-blind males is about 4 per cent of the population; the number of women in whom one X-chromosome is defective for color perception is in the same proportion. If a color-blind male has children by a woman who bears the recessive trait of color blindness (i.e., one defective X-chromosome), half the daughters as well as half the sons will be color blind. The chance of this occurrence is, with the general prevalence of color blindness, 4 per cent of 4 per cent, or 16 in each 10,000. The actual occurrence of color blindness in women is in nearly this proportion.

The transmission of hemophilia (see page 134) follows the same laws as that of color blindness. It appears primarily as a disease of males but is transmitted through the female line. Theoretically, as is the actual case with color blindness, a certain small number of women receiving two defective X-chromosomes should suffer from hemophilia. The disease does not, however, occur among women; it is assumed that other qualities in the defective X-chromosomes prevent their surviving intrauterine life, or at most early childhood.

Mutation.

By mutation is meant a change in the genetic composition of the cell. Such a change may be induced in the seeds of plants and the eggs of insects by exposing them to gene-destroying forces such as the X-ray. With carefully regulated application to avoid death, some of the genes are modified so that the progeny are abnormal. Similar changes also develop among plants and animals "spontaneously," that is, from unknown causes. Thus in a bed of pink carnations grown from cuttings, not from seed, and therefore free from the effects of hybridization, there may appear one which is pink and white striped. It is a spontaneous mutant or "sport." This plant if novel and desirable in appearance—and most mutants are not—may be used to create a new variety of the flower. Similar changes continually occur in all animals—includ-

ing man. Most mutants are so deformed as to be inferior to the stock which produces them; probably the majority do not survive intra-uterine life, but die and are discharged at an early date; some are born and exist as cripples or freaks. It is assumed that occasionally favorable mutation occurs in animals, yielding a superior individual better suited to the environment than the average individual. It is believed further that this favorable mutation plays an important part in evolution and in the survival of a species under changing environmental conditions.

A special type of local mutation is the cause of the disease cancer. The cancer cell is believed to be a cell which has, for reasons still imperfectly understood, undergone mutation in the body and so escaped from the control of the influence normally exercised over the multiplication of cells.

Neoplasms.

A swelling is, by technical definition, a tumor. Some swellings are due to the accumulation of pus or fluid, and some to the excessive multiplication of cells. The first type is usually spoken of as an inflammatory swelling; the term tumor is reserved for the overgrowth of cells. All tumors are correctly classed as neoplasms—new growths. Neoplasms in turn are classified as benign and malignant. In common usage the term tumor is now used to designate a benign neoplasm, and the term cancer a malignant neoplasm.

The distinction between a benign and a malignant neoplasm lies in their mode of growth. In a benign neoplasm—the tumor—the cells of some tissue multiply excessively, but the lump thus formed retains about it the layer of connective tissue or capsule which normally surrounds all organs. The benign neoplasm may cause disfigurement; it may press on surrounding vital structures as is the case with brain tumors; and, if appearing in gland tissue, it may harmfully overexercise the functions of the gland, as occurs in tumor of the pituitary gland which gives rise to acromegaly. The benign neoplasm does not, however, tend to spread to other parts of the body. Its cells undergo an excessive but orderly growth.

A malignant neoplasm does not have a capsule about it; it is a pulpy shapeless mass. Cells broken off from it are in turn carried to other parts of the body in the lymph or blood; new cancers start wherever the cells lodge. This spread of cancer is known as metastasis. The fatal effects of cancer result from the destruction of vital organs either by the primary growth or by those arising by metastasis.

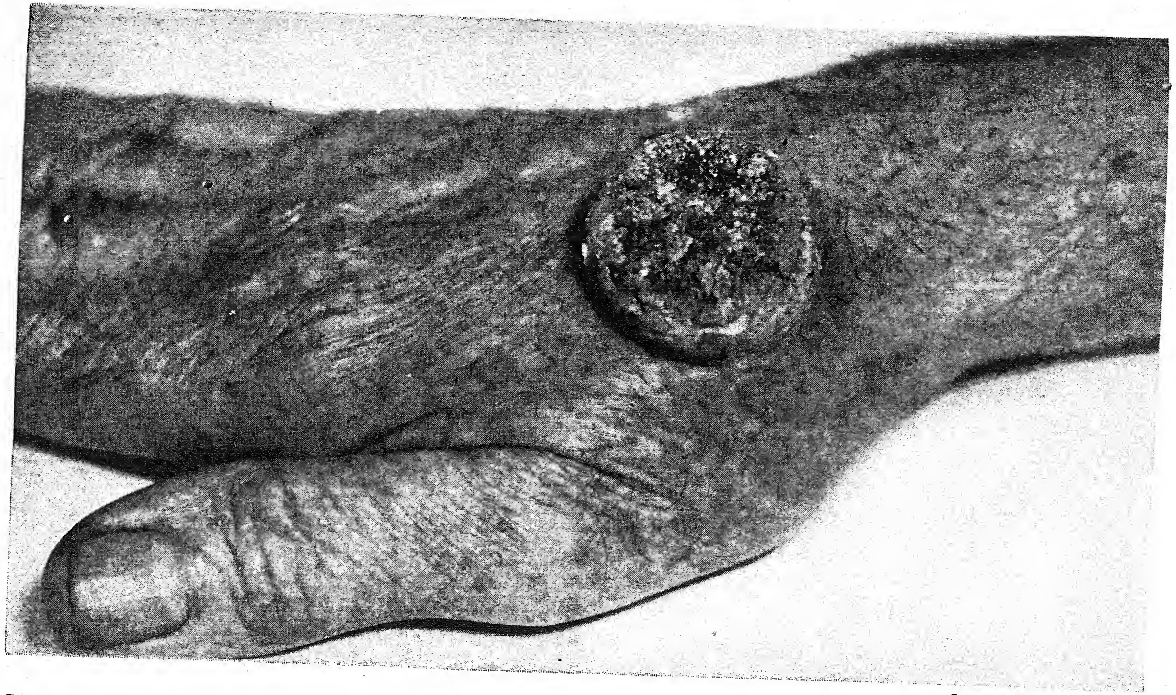
The suffix *oma* after the name of a tissue is used to designate a tumor; thus a swelling from a collection of blood under the skin—a large blood blister—is known as a hematoma; a benign neoplasm of fat is a lipoma, and one in muscle a myoma. A cancer occurring in the skin is an epithelioma; in the glandular tissues as of the breast, digestive, urinary or reproductive tracts, a carcinoma; and in connective tissue, a sarcoma.

All tissue increases in size and repairs its injuries by the multiplication of its cells, but this multiplication is regulated. Thus when the skin is cut, cell multiplication is stimulated; the wound is closed by the newly formed flesh, but, when closed, cell multiplication ceases except for growth or to replace cells which die. The cancer cell, on the contrary, does not stop growing; it continues unrestrained by the normal controlling influences of the body; it grows at the expense and to the damage of the tissue from which it springs.

The Cause of Cancer.

The cause of most cancer is not known, but some of the forces causing cell mutation, hence cancer, have been discovered. Cancer has never been produced experimentally by mechanical forces such as blows or by mechanical irritation; probably injuries play little part in cancer causation in spite of the wide belief that cancer of the breast follows a blow. The blow may lead to the examination of the breast and hence to the discovery of a cancer, or it may hasten the growth of an already existing cancer. Cancers definitely are not infectious; they are not caused by germs. Cancers may, however, be transplanted surgically from one animal to another of the same species and made to grow; the new growth is derived wholly from the transplanted cells. There are also certain cancers in lower animals—and probably some tumors in man—that develop from the action of a filterable virus.

Repeated burning of the skin carried out over many years may occasionally lead to cancer. This fact was first observed among the shepherds of Kashmir who, to warm themselves, carry under their robes and against their abdomens a small earthen vessel of hot coals. Many of them develop cancer of the skin of the abdomen, an unusual locality. X-ray and radium applied repeatedly and excessively to the skin may lead to cell mutation with the production of cancer. X-ray and radium are also used to destroy cancers, and their action may be to induce further and therefore fatal mutation in the cancer cells. There is no danger to the patient in the ordinary use of X-ray as in taking pictures



Courtesy Dr. M. Strauss

PLATE X. Cancer of the skin—one of the several varieties that may develop. This cancer was removed before metastasis had occurred. See page 183.

Cancer cells were first seen and described by the German physiologist Johannes Müller in 1838. Before that time it was believed that cancers were composed of clotted and degenerated lymph and that the growth itself was a local manifestation of a general disease analogous in this respect to the pustules of smallpox. Müller demonstrated that a cancer consists of an abnormal growth of cells and that it is a local abnormality. The disease spreads only when the cancer cells break off and are carried to other parts of the body. The modern knowledge of cancer dates from Müller's discovery.

of the chest or other parts of the body; the danger is to the physician who takes them daily and who does not protect himself against repeated exposure. Sunlight may possibly excite cell mutation and thus predispose to cancer of the skin; cancer of the skin occurs most commonly on those areas exposed to sunlight, and most frequently in individuals whose occupations take them out-of-doors.

Aside from heat, X-ray, and radium, most of the substances now known to cause cancerous cell mutation are chemical. The observation that cancer of the skin is common among men exposed to tar led to the successful attempt to produce cancer on the ear of a rabbit by repeated application of tar. Tar is composed of many different chemical substances and these have been separated and tested to find those which are carcinogenic, that is, cancer-producing. In this way it has been found that the carcinogenic substances in tar have in their chemical structure the so-called phenanthrene ring. This arrangement of molecules occurs in vitamin D and in the sex hormone oestrin. The injection of large quantities of oestrin into mice is followed by cancer of the breast. The implications of present cancer researches are that the action of chemical substances, possibly normal bodily secretions, is the main inciter of cancer. The fact that cancer occurs most commonly after middle life may signify only that the carcinogenic agent has had a sufficient length of time to operate.

The treatment of cancer consists in the removal, or destruction, of all cancer cells before any have escaped from the primary cancer and produced metastasis. Surgery and radiation with X-ray and radium are the only satisfactory methods of treating cancer. Success with either depends upon the early detection of the cancerous growth. After cancer has spread to vital organs the condition becomes inoperable. The tendency of cancer to spread depends in some measure upon the variety; sarcoma is particularly prone to metastasis. The symptoms arising from cancer and the course of the disease are modified by the locality of the growth.

Cancer of the skin is one of the commonest varieties and the least fatal. The growth here is easily detected, but, what is even more important, most skin cancers are only mildly malignant and therefore slow in forming metastases. There is an exception to this fact in the case of cancers starting from moles; they may spread rapidly. Cancer of the skin usually starts as a small roughened painless lump or as a scaly area. Both become ulcerous sores, at the base of which the flesh feels firm and swollen.

Cancer of the lip like that of the skin has a low malignancy and is easily detected in its early stages. It appears first as a scabby lump or a persistent crack in the flesh. Later an ulcer forms; here also the base feels firm and swollen. Cancer of the lip occurs almost exclusively on the lower lip; it is far more prevalent in men than women.

Cancers of the mouth and tongue are usually more malignant than those on the skin. Cancers in these two areas appear at an earlier average age than cancer of the lip, the former usually between forty and sixty, and the latter after sixty. Cancer of the mouth is more common in men than in women and it has been assumed, but without proof, that the use of tobacco may be a contributory factor. Cancer here starts as a lump or thickening on the side or under surface of the tongue or as a painless whitish scab or plaque. The surface breaks down into a ragged ulcer with swollen edges.

Cancer of the breast is some sixty times more prevalent in women than in men. Its earliest stages cannot be detected; its first apparent form is as a lump. All lumps in the female breast are not cancers; many benign neoplasms occur here, and many swellings as the result of chronic inflammatory changes. Childbearing and nursing do not contribute to cancer of the breast.

Cancer of the breast is more often fatal than is cancer of the skin, but less so than cancer of the stomach since the latter cannot be felt as a lump but only suspected from the disturbances in digestion which it produces. These disturbances are in the early stages often indistinguishable from those occurring in minor and temporary disorders of the stomach. X-ray examination is necessary to establish the presence of the cancer, which is usually far advanced by the time such examination is decided upon. It was once believed that gastric ulcers predisposed to cancer; there is little evidence to support this view.

Cancer of the rectum is easier to detect than cancer of the stomach. The earliest symptoms are usually irregularity of the bowels, pain and bleeding. Failure of early detection here often results from mistaking the cancer for hemorrhoids which may show the same symptoms. The difference is readily recognized by medical examination if and when such examination is made.

Cancer of the uterus is in the United States the leading cause of cancer deaths among women. In most other countries the prevalence of this form of cancer is lower. The disease develops most commonly on the neck or cervix of the uterus. It appears as a chronic inflammation followed by an ulcerous sore. Usually bleeding is the first symptom

noticed. Bleeding occurring between the normal periods or after the menopause does not necessarily signify cancer, but it does signify need for an immediate and thorough gynecological examination.

Increase of Cancer.

In spite of greatly improved methods of diagnosis and treatment, the deaths from cancer have in the last forty years increased enormously. In 1900, cancer occupied tenth place among the leading causes of mortality, with 63.0 deaths per 100,000 of population. In 1934 it reached second place, with 115.5 deaths per 100,000 of population. Age has a profound influence upon the occurrence of cancer; thus with the 1934 rate of 115.5 per 100,000 of population for all ages, the rate at 20 was only 6.1; at 30 it was 21.4; at 40, 84.0; at 50, 109.8; at 60, 400.0; at 70, 692.0; and after 75, 107.7. In comparison, the deaths from diseases of the heart and blood vessels amount to 213, and those from automobile accidents to 28.4 per 100,000 of population. The main cause for the rise in the number of deaths from cancer (and also diseases of the heart and blood vessels) is the increase in the average length of life. In 1900 the average length was 49 years; in 1934 it was over 60. This prolongation has resulted largely from the control of acute infectious diseases such as typhoid by sanitation, and from the lowering of infant mortality by better hygiene. Since, as noted, the prevalence of cancer increases with age, a shift in the average age of the population must inevitably result in an increase in cancer. The present rise is therefore due not to any decadence of civilization or to a plague or epidemic, but to a readjustment to an increasing length of life.

CHAPTER XXIII

THE PRINCIPLES OF INFECTION, IMMUNITY, AND ALLERGY; CERTAIN INFECTIOUS DISEASES

ONE OF THE MAJOR STEPS IN THE MEDICAL PROGRESS OF THE PAST WAS IN defining diseases as entities, that is, recognizing that smallpox and measles and diphtheria were different diseases, each having what might be termed its natural history. The differentiation of diseases has usually been made first on the basis of the symptoms that develop during illness; it becomes far more positive when the cause of the disease is also known. Thus diphtheria when fully developed can be recognized from the symptoms it presents; but it can be diagnosed early and with certainty by finding diphtheria bacilli in the throat. Prevention or cure of a few diseases has been discovered accidentally before the causes of the diseases were known, but usually the discovery of cause is a necessary step toward control.

The essential causative agent has been found for more than 80 per cent of the diseases now recognized as entities. All the disease-causing agents that have been so far discovered occur on the outside of the body and are foreign to it. Most of the diseases for which the primary causes have not been found are among those classed as disturbances of metabolism, such as gout and diabetes. About 30 per cent of diseases are caused by chemical or physical agents, that is, inanimate agents; such diseases include carbon monoxide poisoning, morphinism and alcoholism, caisson disease, wounds, burns, frostbite, silicosis, and the like. Of the remaining 50 per cent of all recognized diseases for which the cause is known, the agent is animate; it is a living parasite such as a bacterium, a fungus or a protozoon.

The discovery of the parasitic cause of infectious diseases, that is, that these diseases result from the action of bacteria and other animate agents, was probably the most important event in medical history. Certainly, judging from its effect on the human race, it was one of the most important in all history, for it opened the way for modern sanitation and modern preventive medicine. This discovery was made in the eighteen-seventies. Lister demonstrated the fact that pus formation in wounds and the fever that accompanied it were due to the growth

of bacteria on the injured flesh. He introduced antisepsis and asepsis into surgery. Pasteur and Koch showed that infectious diseases were due to the growth of parasitic microorganisms in the body.

Forms of Parasitic Agents.

The animate agents causing disease may be broadly classified into five groups: (1) bacteria; (2) fungi; (3) protozoa; (4) worms; (5) viruses.

Bacteria are microscopically small one-celled organisms more closely related to plants than to animal forms of life. There are many different kinds of bacteria, distinguished by their appearance, their reaction to stains, and their mode of growth when cultivated in the laboratory. Most bacteria do not cause disease; they are incapable of multiplying on living human flesh. Such bacteria, far from being harmful, are essential to life, for their action brings about many important changes such as the disintegration of organic matter in the soil. Only a few of the vast number of different types of bacteria are parasitic to man; they are called pathogenic—disease-originating—bacteria.

For purposes of general classification bacteria are designated according to their shapes as bacilli, cocci, and spirilla. A bacillus is rod-shaped. The bacilli are often named after the diseases they cause, as tubercle bacillus and diphtheria bacillus. Some bacilli are equipped with slender hair-like projections called flagella, the waving of which gives motility to the organisms. The typhoid bacillus is thus flagellated and motile.

Cocci are round or oval; they are sometimes designated by the diseases which they cause, as the gonococcus and pneumococcus. The designation may also be according to the mode of growth, as the streptococcus which forms a chain of cocci as it multiplies, or the staphylococcus which forms a block of cocci as it multiplies. Again, further descriptive designation may be given by some feature of the action of the coccus, as the hemolytic—blood-dissolving—streptococcus.

Spirilla are thread-shaped or corkscrew-shaped microorganisms. Some forms of this general group are difficult to distinguish from the protozoa and there is difference of opinion as to whether all are bacteria.

The microorganisms called Rickettsia are smaller than ordinary bacteria and their exact classification is uncertain; they live in lice and ticks and may infest man to cause such diseases as typhus and Rocky Mountain spotted fever.

The *fungi*, including yeasts, are, like the bacteria, plants, but many

forms in this group are multicellular. Bacteria multiply by simple division, one organism dividing in half to form two, each of which then grows to full size and in turn divides. Many of the microscopic fungi divide in this way, while others, particularly the larger ones, develop many spores which act as seeds. Certain bacteria such as the botullinus and tetanus bacilli may also develop spores, but only singly and not for multiplication. In forming spores the bacilli shrink down to a smaller mass. The spores thus formed are far more resistant to heat and drying than are bacteria; they may exist dormant for long periods of time and under adverse conditions, but they develop into the active form of the bacteria when brought into suitable surroundings. The fungi in causing disease rarely penetrate deeply into the body; instead they live in the surface tissue. Some attack the mouth and lungs; more commonly they infest the skin as in ringworm.

The *protozoa* are unicellular animals; they may increase in numbers by simple division as do bacteria, or by sexual multiplication. Amebic dysentery and malaria are among the more common diseases caused by protozoa; in addition, many so-called tropical diseases, such as African sleeping sickness and elephantiasis, result from infection by protozoa.

The *worms* infecting human beings have been discussed in Chapter III.

The *viruses*, so-called, constitute one of the major unsolved problems of modern medicine. They have not as yet been classified; little is known of their characteristics; and there is uncertainty as to whether all or any are living organisms. The viruses are infective agents which are too small to be seen with the microscope. They maintain their infective properties when passed through a porcelain filter too fine to admit the smallest known bacteria; hence the term filterable virus. The chemical isolation of the viruses causing certain plant diseases has shown these particular viruses to be closely allied to protein in composition, and probably non-living. The belief is that this virus substance when brought on to living tissue stimulates it to form more of the virus, and the tissue is injured by the virus it has itself manufactured.

Infection.

The word infection is from the Latin, meaning to stain or contaminate. The essential feature in infection is the entrance into the body of an alien living organism. Ordinarily, and always with bacteria,

the number of the organisms which reach the body in infection is too small to produce the symptoms of disease. The ill effects develop only after the invading organism has adapted itself to the new host and multiplied in large numbers. The delay which occurs between the time of infection and the appearance of the first symptoms of disease is known as the incubation period. This period is different for different diseases and somewhat variable for any one. Thus the incubation period for streptococcus wound infection may be a few hours; for typhoid fever one, two or even three weeks; and for leprosy, months or years. The rate at which bacteria may grow in a highly favorable environment is prodigious. Division may occur as often as once each half hour; at this rate and in geometric progression the progeny of a single bacterium would in fifteen hours be 1,000,000,000 bacteria. Most infective organisms are resisted by the host, so that multiplication does not ordinarily occur at such an enormous rate.

The Spread of Infective Agents.

The infective agent does not profit from the death of its host, but dies with it. No living agent arises spontaneously; it comes only from another of its kind, and therefore each case of an infectious disease comes from some previous case of the same disease. For its perpetuation the parasite must have modes of escape and transfer to new hosts. The elaborate methods for transfer employed by some intestinal worms have been discussed previously (see page 62). Bacteria leave their host in ways depending upon the location of the disease within the body. Thus in tuberculosis of the lungs the tubercle bacilli are discharged in the sputum. In cholera, typhoid fever and bacillary dysentery the disease is particularly centered in the intestines, and the organisms leave in the fecal matter which is greatly increased in amount. In rabies the disease is centered primarily in the nervous system, but the virus is secreted in the saliva. In many diseases the infective agent is discharged in the nasal secretions; this is the case for diseases local to this region such as the head cold, but it may occur wholly incidentally in diseases which are general throughout the body as in measles.

The Entrance of Infective Agents.

Most infective organisms require special points of entry into the body before they can cause disease. A few, such as certain strains of streptococci, the plague bacillus, the anthrax bacillus and the bacillus of tularemia, can multiply on any part of the body where they can

find an entrance through a break in the skin. A pin prick suffices to open the way for them. A great majority of organisms, however, must be brought to some specific locality in the body before they can cause infection. Thus the typhoid bacillus is harmless in an open wound, but infective on the surface of the intestine; the tetanus bacillus is harmless in the intestine, but it causes lockjaw when inserted beneath the skin.

Course of Infection.

Every infectious disease involves the reaction of two living organisms, and each disease is caused by a different organism with its own peculiarities. Therefore each disease has special characteristics that require separate description. There are, however, certain modes of behavior followed by parasites that allow some general description.

The area involved in an infection varies with the nature and virulence of the bacteria. Virulence is a measure of the ease with which the organism adapts itself to the body, overcomes the forces that resist it and multiplies. Those of low virulence are held near the point of entry and their growth is restrained; thus the staphylococci of low virulence that cause pimples and minor infections in small cuts rarely spread beyond this point. A virulent streptococcus similarly introduced beneath the skin may spread within a few hours into the lymph channels and from there into the blood. It may actually multiply in the blood and be spread to every part of the body. This condition is known as septicemia or "blood poisoning." Even a virulent bacterium may stay at the point of entry if it is the nature of the organism to behave in this way. Thus the diphtheria bacillus remains localized on the mucous membrane of the nose, throat and trachea, and occasionally on wounds in the skin.

Bacteria exert their harmful action mainly through the formation of substances that poison the host. These poisons may consist of broken-down and partially digested proteins which come from the destruction of the bacteria. Such material from any source is poisonous, a fact that has been noted in connection with burns (see page 306) in which the absorption of the destroyed flesh of the body may lead to illness and even death. Such poisons are probably not specific for any one sort of bacteria but common to all. Some bacteria, but by no means all, are capable, while living, of forming specific toxins which poison the body. Thus broth in which diphtheria bacilli are grown but later removed by filtration, is highly poisonous because

of the toxins it contains. Injected into the body, the toxin causes the general symptoms of diphtheria, but since it contains no organisms, the membrane in the throat is not formed and the illness is not infectious. The bacterial toxins are apparently proteins, and under their action the body is capable of forming neutralizing substances or antitoxins.

When an organism has infected the body, gone through its period of adaptation and multiplied extensively, the symptoms of disease develop. These symptoms indicate the body's reaction to the injury and poisoning caused by the organism. The symptoms may be local and appear as inflammation at the point of entry as in abscess formation or sore throat. Frequently no local symptoms appear and the first indication of disease is fever.

Resistance and Immunity.

Some animals cannot acquire certain diseases; they are said to have a natural immunity. Thus the frog, fish, and other cold-blooded animals cannot acquire most diseases of warm-blooded animals; with the exception of tularemia and psittacosis, the diseases of birds can rarely be transferred to mammals; cattle frequently suffer from tuberculosis, but the cat and dog rarely; all rodents are susceptible to plague, but cattle are not. The essential feature in this natural immunity of animals to certain diseases is the inability of the infective agent to multiply on their flesh. Most bacteria and other parasites are adapted to only a narrow range of conditions in the host such as body temperature and alkalinity of the blood; when the conditions are unsuitable they cannot thrive on the flesh, and the animal is then naturally immune. Man occupies an unfortunate position in regard to natural immunity; the conditions of his flesh suit a greater number of parasites than perhaps those of any other animal. He is susceptible to most of the diseases of other animals and has in addition a number of his own against which brute animals are immune, such as smallpox, chicken pox, measles and scarlet fever.

It has long been recognized that recovery from certain diseases, such as measles, smallpox, typhoid fever, yellow fever and plague, virtually insures the individual against a recurrence of these diseases. He acquires what is known as an active immunity. The change which has taken place in his body to confer this protection consists largely in the excitation of certain cells of the body to greater activity in contending with and overcoming the specific infective agents. The part played by the white cells in ingesting and destroying bacteria has been

discussed (see page 131); a similar action, to even more pronounced degree, is exercised by large cells found in connective tissue, the walls of blood capillaries and in the blood itself. The cells are called macrophages. They are particularly numerous in the granulating tissue of healing wounds.

When a protein foreign to the body is introduced into it a change develops in the cells. Their reaction toward this particular protein is altered and made more sensitive. At the same time chemical substances called antibodies appear in the blood and tissues; they are an expression of the change which has occurred in the cells. A substance capable of making the cells senstive and leading to the formation of antibodies is known as antigen. The cellular sensitivity developed to any antigen is highly specific for that particular antigen. Most proteins can act as antigens, but they do so only when introduced into the flesh and not when taken into the alimentary tract. Digestion in breaking them down into amino acids destroys their powers of producing antibodies.

Bacteria contain proteins which are characteristic for each organism; consequently the presence of bacteria in the body may excite a specific sensitivity of the cells and formation of the antibody. It is in this manner that recovery from disease may occur and immunity be acquired. The sensitivity developed by the cells persists after the disease has passed. In case of subsequent infections the cells, now highly sensitized toward the proteins of this particular organism, immediately seize upon and destroy it; no opportunity is afforded for the organisms to multiply. The antigen in the blood or serum of an individual who has acquired immunity to a disease may, when injected into another person, confer some slight immunity; meningitis, measles and infantile paralysis are sometimes treated in this way.

For certain diseases some degree of immunity can be developed without infection occurring. Vaccines are used for this purpose. A vaccine consists of a suspension of dead bacteria; the organisms are injected under the skin. The bacteria, since they are not living, cannot multiply and cause disease, but their antigens may nevertheless excite tissue sensitivity and antibody formation. The use of vaccines against typhoid and paratyphoid fevers and dysentery has been strikingly successful. For some diseases, especially those caused by viruses like the common cold, vaccines are not particularly effective.

These toxins formed by diphtheria and tetanus bacilli are proteins and they therefore act as antigens to excite the cells of the body, to

produce substances similar to antibodies but in this case called antitoxins. An antitoxin is capable of neutralizing a toxin and thus rendering it non-poisonous. Antitoxins persist in the blood after recovery from disease and thus confer active immunity. The antitoxin formed in the blood of one individual can also be used to treat or prevent diseases in another. The antitoxin serums thus used against diphtheria and tetanus are obtained from animals, usually horses. They are prepared by injecting repeatedly into the animals small and therefore non-fatal doses of the toxin and subsequently withdrawing blood and separating the serum containing the antitoxin. Similar antitoxins are prepared against snake venoms.

Allergy.

Allergy is hypersensitivity to a protein. The underlying condition in allergy is apparently closely related to that of active immunity. But allergy, instead of affording protection against foreign proteins, gives rise to unpleasant and even dangerous symptoms. The condition is considered by some scientists to be an incomplete immunity. Any substance which can give rise to immunity can, under certain conditions, also give rise to allergy. Thus if a minute amount of some protein, for example horse serum, is injected into a guinea pig, hypersusceptibility develops in a few days. The injection of the same material is then followed by a violent bodily reaction called anaphylaxis.

In human beings allergies appear to be somewhat different from the simple induced protein sensitivity of the guinea pig and they may develop in ways that are not understood. The individual affected, on exposure to the protein against which he is sensitive, may exhibit such conditions as hay fever, cat or horse fever, food allergy, asthma, and serum sickness. Occasional individuals may even give allergic reactions to physical agents such as sunlight, heat and cold; it is possible in these conditions that the agent may modify the individual's own protein, rendering it poisonous.

Antitoxin serums used against diphtheria and tetanus contain animal proteins. In occasional individuals who are naturally allergic to these particular proteins, a serious and immediate reaction known as serum shock may occur on injection of the serum. This condition is rare. Some individuals, given large doses of serum, may show a much milder disturbance known as serum sickness. The symptoms appear usually after the lapse of several days and consist of urticaria (hives), itching and swelling of the legs, arms and face. If the first dose of

serum is borne without ill effect there is usually little danger in a second or third dose given at some later period. Human beings do not apparently develop protein sensitivity with the ease of the guinea pig.

The proteins of pollens are the most common causes of allergic reactions in human beings. The pollen, when inhaled, is arrested on the mucous membrane of the respiratory tract, mainly the nose. If there is hypersensitivity to this particular protein the tissue reacts; it becomes red and swollen; the mucus flows profusely. Asthmatic attacks may develop, with difficulty in breathing. This condition, although called hay fever, results from many different sorts of pollen. The pollen of trees is responsible for most of the cases in the spring; that of the grasses in the summer, and of the weeds, such as ragweed, in the late summer and fall.

Certain individuals are allergic to particles carried in the air from hair, feathers, paper and leather. They exhibit the symptoms of "hay fever" or even asthma when they come near the material to which they are sensitive. Still others may exhibit an allergic reaction to fungi, such as wheat rust or corn smut, to the scales from insects, and particularly the bites of the insects. Food idiosyncrasies, as discussed on page 44, are allergic in nature; the most common offenders are milk, eggs and wheat.

The discovery of the particular substance to which an individual is sensitive is not difficult if, as in hay fever, the symptoms appear only at certain seasons or, as in food allergies, only after certain foods are eaten; the discovery may, however, be very difficult if the relation of the reaction to some common source is not obvious. The physician may then make tests with all possible substances by putting a minute amount in a needle prick made in the skin of the arm. The development of a red area about the point of test indicates an allergy.

When the cause of the allergy is discovered it may be possible to escape the unpleasant reaction by avoiding the exciting substances. Medicinal substances prescribed by the physician may give some relief in attacks where the cause cannot be avoided. In some cases it is possible to overcome the allergy and convert it into an immunity by the repeated administration in increasing amounts of the substances causing the reaction.

The Specific Infectious Diseases.

In previous sections at appropriate points, thirty-six major infectious diseases have been discussed. These diseases, together with nine ad-

ditional ones to be dealt with in this chapter, are listed in Table XVI. The causative agent and the incubation period are given for each, and also the pages on which the disease is described.

TABLE XVI.—THE MORE IMPORTANT INFECTIOUS DISEASES WITH CAUSATIVE AGENT, INCUBATION PERIOD AND INDEX TO TEXT

Name of Disease	Causative Agent	Incubation Period	Page on Which Described
	A.—Diseases Caused by Bacteria		
1. Anthrax............	Bacillus anthracis	1 to 5 days	309–10
2. Cholera............	Spirillum cholerae	few hrs. to 5 days	71
3. Diphtheria.........	Bacillus diphtheriae	2 to 5 days	189
4. Dysentery (bacillary)	Bacillus dysenteriae (several types)	1 to 2 days	70
5. Erysipelas	Streptococcus	1 to 2 days	308–09
6. Gonorrhea.........	Gonococcus	2 to 6 days	567
7. Influenza...........	Bacillus influenzae (probably also virus)	1 to 3 days	234–35
8. Leprosy............	Bacillus leprae	mos. to yrs.	313
9. Meningitis (epidemic)	Meningococcus	1 to 3 days	348–49
10. Paratyphoid fever...	Bacillus paratyphosus (several types)	5 days to 2 weeks	70
11. Plague.............	Bacillus pestis	2 to 8 days	318–19
12. Pneumonia (lobar)..	Pneumococcus	1 to 2 days	233
13. Pneomonia (bronchial)	Variable	......	232
14. Rat bite fever.......	Spirochaeta morsus muris	1 to 3 weeks	329
15. Rocky Mountain spotted fever	Dermacentrosenus rickettsii	4 to 7 days	324
16. Scarlet fever........	Streptococcus	1 to 2 days	188
17. Syphilis............	Treponema palladium	10 days to 3 mos.	564–67
18. Tetanus............	Bacillus tetani	4 to 9 days	562–63
19. Tonsillitis..........	Streptococcus	1 to 2 days	187
20. Tuberculosis........	Bacillus tuberculosis	......	235–42
21. Tularemia..........	Bacillus tularensis	1 to 6 days	325
22. Typhoid fever......	Bacillus typhosus	1 to 3 weeks	70
23. Typhus fever.......	Rickettsia prowazeki	......	317
24. Whooping cough...	Bacillus pertussis	1 to 2 weeks	561–62
	B.—Diseases for Which Infective Agent Is not Known		
25. Chicken pox........	Probably virus	11 to 20 days	555–56
26. Coryza (head cold)..	Probably virus	1 to 2 days	228–31
27. Encephalitis.......	Probably virus	......	354–55
28. Hydrophobia.......	Probably virus	Usually 20 to 60 days	326–27
29. Infantile paralysis...	Probably virus	1 to 14 days	351–53
30. Measles............	Probably virus	8 to 11 days	554–55
31. Mononucleosis......	Probably virus	......	132
32. Mumps............	Probably virus	12 to 26 days	561–62
33. Rheumatic fever....	Probably virus (Possibly streptococcus)	......	175–76

TABLE XVI—*Continued*

Name of Disease	Causative Agent	Incubation Period	Page on Which Described
34. Rubella (German measles)	Probably virus	14 to 18 days	555
35. Smallpox..........	Probably virus	10 to 16 days	556–58
36. Psittacosis	Probably virus	8 to 15 days	325
37. Yellow fever.......	Probably virus	2 to 6 days	323–24
	C—Diseases Caused by Protozoa		
38. Amebic dysentery...	Endameba histolytica	......	67
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42. Ascariasis.........	......	......	64–65
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44. Hookworm disease..	......	......	65–67
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Measles.

Measles is one of the so-called diseases of childhood. Any disease thus designated is one that is highly infectious and widely prevalent, and against which there is no natural immunity or adequate means of protection. Such a disease occurs in childhood because it develops on the first exposure. At one time smallpox was a disease of childhood and was as common as measles is today; as a result of prevention by vaccination, smallpox is no longer virtually universal. There is no similar protection against measles. A child born of a mother who has had measles is immune to the disease for about four months; thereafter it becomes susceptible and this susceptibility is carried throughout life, so that if by reason of isolation in a rural community the disease is escaped in childhood the individual may acquire it at any period of life. One attack usually gives complete immunity.

The mortality from measles is low except for infants; during the first three years the death rate may be as high as 15 or 20 per cent; by the age of ten it falls to about 1 per cent and remains at this figure through adult life, but rises again in the aged. The fatalities result mainly from bronchopneumonia (see page 233), which is a common complication.

The incubation period of measles lasts from eight to eleven days.

The first symptoms to appear resemble those of an infection of the upper respiratory tract. The nose runs, the eyes are sore and there is fever and illness. At this time small spots may be seen on the mucous membrane of the mouth and material scraped from this surface when stained shows under the microscope peculiar cellular bodies which are diagnostic of the disease. The distinguishing eruption of the disease does not develop until the third or fourth day of this stage when small red spots similar to flea bites appear upon the skin of the face and spread slowly over the body. The period of eruption lasts from four to six days. After the rash fades the skin peels off in small scales.

Measles is spread by contact. The secretions from the nose and mouth carry the infective agent. It is present in these secretions during the first stage, and hence before the typical eruption has appeared. This fact makes it difficult to guard against the transmission of the disease. Although it is a common disease, measles is not to be regarded lightly; even during the period of convalescence constant watchfulness and care are necessary to prevent the development of pulmonary complications. Many cases of bronchopneumonia and tuberculosis arise from "catching cold after measles."

The attack of measles may be made less severe by the injection of blood from an individual convalescing from the disease or even from one who has some time previously had the disease. Fluid squeezed from the placenta obtained after childbirth can also be used for this purpose. These measures may be used as a prophylaxis in the event that infants are exposed to infection.

German measles or rubella is a disease distinct from measles; it attacks those who have had measles as well as those who have not. It resembles measles, but is much milder and is never fatal. It differs in that the lymph glands, particularly in the neck and back of the ears, become swollen. The disease is rarely followed by complications, but in rare instances the brain may become inflamed and a mild and usually temporary encephalitis develops. This complication is one that may occasionally occur in nearly any one of the diseases caused by a virus.

Chicken Pox.

Chicken pox is a contagious disease which is rarely fatal. The period of incubation is eleven to twenty days. Fever then develops and within twenty-four hours the typical eruption appears. Small red spots rise

above the surface of the skin. Within a few hours these spots are transformed into vesicles containing a clear fluid. A day or two later pus replaces the fluid. The pustules gradually shrivel and are converted into scabs which fall off and as a rule leave no scar unless they have been scratched.

Smallpox is sometimes mistaken for chicken pox, particularly when the case is mild. At the beginning of an epidemic the correct diagnosis may not be made until a fatal case occurs.

Smallpox.

Smallpox is an ancient disease; it existed in China many centuries before the Christian era. At the time of the Crusades it spread throughout Europe. In this day of general vaccination it is difficult to realize that smallpox was once one of the scourges of mankind; it depopulated cities and almost exterminated nations. During the eighteenth century approximately 60,000,000 people died of the disease in Europe.

Smallpox was introduced into the western hemisphere by the Spaniards fifteen years after the discovery of America. Within a short period thereafter three and one-half million persons in Mexico are said to have died of the disease. Half of the American Indians died of smallpox. In Iceland in 1707, 18,000 perished out of a population of 50,000. The epidemic of 1752 in Boston furnishes an example of the wide ravages of the disease. At that date the population of Boston was 15,684. Of this number, 5998 had previously had smallpox. During the epidemic 5545 persons contracted the disease in the usual manner, 2124 took it by inoculation, and 1843 fled from the city to avoid infection. There were therefore left in the city only 174 who had not had smallpox.

Smallpox is one of the most virulent of the infectious diseases; persons exposed to it, unless they have had the disease or are protected by vaccination, are almost invariably attacked. The death rate may rise as high as 35 per cent. The period of incubation is about twelve days. The disease is then usually ushered in by intense headache, severe pain in the back, and vomiting. There is high fever. The characteristic eruption appears about the fourth day. The spots are raised above the surface. At first they are red, but subsequently they change into pustules. With the first appearance of the eruption, the fever falls and the general symptoms subside, but both return when pus forms in the vesicles. During the third or fourth week of the disease the pustules

break and exude their pus, or they dry and form scabs. In severe cases deeply pitted scars are left after the pustules have healed. Milder cases may heal without scars.

The disease appears in several types. In the mildest form the pustules are some distance apart and each is distinct. In a more severe form the pustules run together, so that a sheet of pus spreads beneath the surface of the skin of the face and extremities. In still another type there is hemorrhage into the skin, giving rise to the name "black smallpox."

Prophylaxis by Inoculation.

Prior to the introduction of vaccination the only prophylaxis against smallpox was inoculation with the virus of the disease. Material was taken from the vesicle or pustule of a mild case of smallpox and introduced into a scratch in the skin. The disease which develops is a form of true smallpox, and although it is usually mild, it may be serious or even fatal. Inoculation is an old custom practiced by the Chinese from time immemorial. It was introduced into western civilization by Lady Mary Montagu, who learned of the method in Constantinople, and had her own boy "engrafted" with successful results. The practice soon became popular in England (1721) and was introduced into America by Dr. Boylston of Boston. Washington had the men of his army inoculated. Vaccination with cowpox has now completely replaced the practice of inoculation.

Prophylaxis by Vaccination.

Cowpox is an eruptive disease of cattle which is transmitted as a mild local disease to persons handling the animals. For centuries it was a popular belief among farmers that cowpox protected against smallpox. Dr. Jenner of England became convinced of the truth of this belief, tried it experimentally, and, in 1798, introduced vaccination. He proved its effectiveness by vaccinating a boy, and then inoculating him with smallpox. No smallpox resulted.

Vaccination was introduced into the United States in 1800. In Boston in 1802 a crucial demonstration was made of its efficiency. Nineteen boys were vaccinated. Three months later twelve of them were inoculated with smallpox, but none contracted the disease. At the same time two boys who had not been vaccinated were inoculated with smallpox; both contracted the disease. Virus was then taken from the two boys

with the disease and inoculated into the nineteen who had been vaccinated, but still they did not contract smallpox.

Efficacy of Vaccination.

The efficacy of vaccination as a prophylaxis is illustrated on a larger scale by the diagram in Figure 89, showing the death rate from smallpox per 10,000 inhabitants in Prussia, Holland and Austria. In Prussia vaccination was legally compulsory for all infants, with revaccination at twelve years of age. In Holland vaccination of children was compulsory before they entered school. In Austria vaccination was not compulsory during the times given.

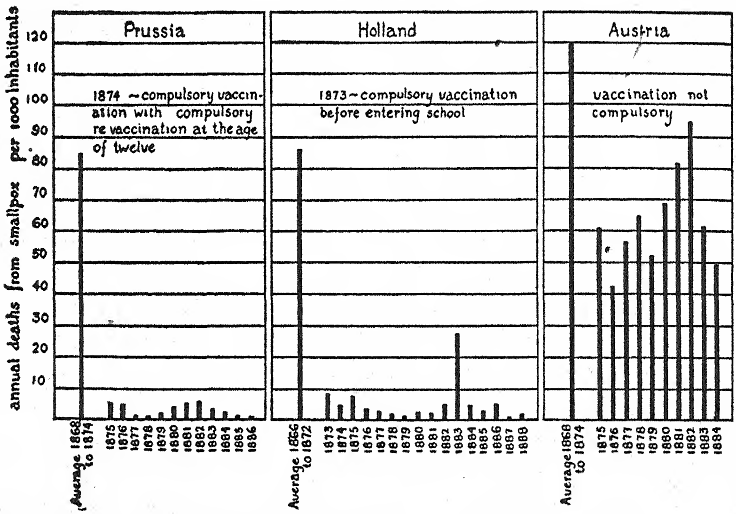

Figure 89. Prevalence of Smallpox in Relation to Compulsory Vaccination.

Smallpox is the most widely distributed of all plagues. Nevertheless, nearly one-fifth of all cases reported occur in the United States. Vaccination is not rigorously enforced by law throughout this country. Unfortunately, the virus of smallpox does not respect state boundaries, or remain where legislation favors it. States which do not have compulsory vaccination and small localities where the enforcement of the law is lax constitute centers from which smallpox may spread. Eradication of the disease is thus prevented. This circumstance is particularly unfortunate in view of the fact that those who are most commonly killed by the disease—the children—have no part in making the laws.

Alleged Dangers of Vaccination.

The opponents of vaccination allege dangers from vaccination, but these dangers have been greatly exaggerated. Some of these people claim that the vaccine virus is derived from a human subject and that human diseases such as syphilis may be transmitted. This idea may have had some basis a century ago, but in this country vaccine virus is no longer obtained from human beings, but from calves. Calves do not have syphilis or any common disease, except cowpox and tuberculosis, which could be transmitted to man. Tuberculosis is carefully eliminated in the stock used for manufacturing virus. Moreover, both state and federal governments maintain a close supervision and examination of all virus, so as to insure its freedom from contamination. Vaccine virus is an infinitely cleaner product than the purest milk.

Vaccination is not, however, an absolutely harmless procedure. Its danger lies in the fact that a minute scratch is produced in the skin and that this scratch is subject to the same risk that might occur in a scratch from any other origin. Even a pin prick or razor scratch may result in death. Such occurrences are, however, rare. Infections from vaccination result only from lack of cleanliness and neglect. Under modern conditions it is extremely rare for serious illness to follow vaccination. The United States authorities vaccinated 3,515,000 inhabitants in the Philippine Islands without a single death or even serious complication.

Tetanus, or lockjaw, occasionally complicates the wound from vaccination just as it may any other wound. Although the tetanus bacilli, or spores, are commonly found in the intestinal tract of cattle and in manure, their presence in vaccine virus results only from gross carelessness, and the strict government inspection of all virus precludes the possibility of such contamination. Over 31,000,000 doses of vaccine virus were used in the United States during the period 1904 to 1913, inclusive, and only forty-one cases of tetanus followed the vaccination. There were, of course, several thousands of cases of tetanus from ordinary wounds during this same period. The average incubation period for tetanus is from four to nine days. In the forty-one cases of tetanus the average time between the vaccination and the development of tetanus was 20.7 days. Therefore, in the majority, if not all, of these cases, the infection was received ten or more days after vaccination. Many of the cases following vaccination gave a history of having the vaccination scab removed in some way, thus permitting the infection of the wound. When the scab reformed, the tetanus bacilli

were sealed from the air, that being the only condition under which tetanus will develop. Bandages and closed shields also favor the anerobic conditions suited to the development of tetanus; they should be avoided. This precaution and cleanliness remove any danger from tetanus.

Cowpox, from which vaccine virus is derived, is closely related to human smallpox. Cattle are not subject to smallpox, but when the virus from human smallpox is introduced into the skin of a calf, cowpox results. When smallpox is thus converted into cowpox it remains fixed as such and never reverts to smallpox. Vaccine virus is obtained, under conditions of the most thorough cleanliness, from the pustule which forms on the skin of the calves. The collected material is mixed with glycerin, ground into a pulp, and dispensed in hermetically sealed tubes.

Vaccination is performed by introducing the vaccine virus into the skin. The skin is first cleaned and then gently scratched with a sharp point until a shallow furrow is produced, but the skin is not cut deep enough to draw blood. The virus is then rubbed into the wound. The outer surface of the upper arm is the most common site for the operation, although the leg is sometimes selected. The arm is the preferable site, for it is less exposed to injury and infection. The primary wound of the vaccination soon heals. At the end of three or four days one or more small red spots appear. About the fifth day these change to vesicles which are surrounded by a swollen and inflamed area. By the seventh day the vesicle has grown to full size and its contents turn yellow. The skin feels hot and painful. The axillary lymph glands are swollen and tender. About the ninth day the inflammation subsides and by the twelfth the pustule dries, leaving a brown scab which finally drops off.

Immunity to smallpox appears about the eighth day of the vaccination. The protection is usually absolute for about seven years, and then gradually fades. This fact makes it necessary to revaccinate in order to afford a continuous protection. The best sequence of vaccination is the first year, and again at ten to thirteen years. It is usually unnecessary to vaccinate a third time unless there is definite exposure to smallpox. All persons known to be exposed to smallpox should at once be vaccinated unless they have had the disease or have recently been successfully vaccinated.

It is commonly asserted that if revaccination fails to take, the subject is therefore immune; but vaccination may fail for many reasons

other than immunity. Sometimes persons are unsuccessfully vaccinated three, four, or even more times before a typical "take" is obtained. A person who has once been vaccinated may in very rare instances contract smallpox; but the disease is then of a mild form, the severity depending upon the length of time that has elapsed since the vaccination.

Mumps.

Mumps is an infectious disease, of which the main manifestation is inflammation of the parotid gland (see page 27). The gland swells and is painful, but pus rarely forms in it and the swelling usually lasts less than a week. Slight fever accompanies the disease, but the constitutional effects are usually mild. Children are not as susceptible to the disease as they are to measles, and a more intimate contact is necessary for its transmission. The average incubation period is from twelve to twenty-six days.

The disease rarely results in death, and complications do not often follow in young children. In boys during the adolescent period, and in men, mumps may lead to inflammation of the testicles. In such cases one or both of the testicles becomes swollen at about the eighth day of the disease. This complication is particularly liable to occur if the boy is allowed to leave his bed. In severe cases the testicle involved becomes small and is sterile. Usually only one testicle is so affected. But even when both are damaged the sexual virility is, as a rule, retained. Mumps in women is, in rare cases, complicated by inflammation of the ovaries.

Whooping Cough.

Whooping cough, or pertussis, is an infectious disease characterized by a catarrhal inflammation of the respiratory passages, accompanied by a convulsive cough which ends in a long-drawn inspiration or "whoop." In late childhood it is a mild disease, but in infancy it may be fatal. Infants are highly susceptible to this infection. The disease attacks adults as well as children and in the aged it is sometimes followed by bronchopneumonia. One attack usually confers immunity.

The incubation period of whooping cough is from one to two weeks. The onset is gradual. The symptoms at first are those of a head cold with a slight cough. After lasting for a week or ten days, the cough, instead of subsiding, becomes more severe. The characteristic attacks of coughing then develop, and vary in frequency according to the

severity of the disease. These attacks start with a series of fifteen or twenty forcible coughs, between which the breath is not drawn in. The child becomes blue in the face, and then with a deep inspiration draws air into the lungs, making the "whoop" from which the disease derives its name. The child suffers severely during the paroxysm and often vomits afterward.

The prevention of the disease consists in avoiding contact with those who have it, but this is particularly difficult because this disease may be so mild that the child is able to remain at play; furthermore, the period during which the infection may be transmitted varies from six weeks to two months even though the "whoop" has ceased. In mild cases among adults the characteristic "whoop" may not appear at all, but these cases may also spread the disease. Both whooping cough and measles commence with what is apparently a head cold. This reason alone, even apart from the possible serious consequences of colds, should emphasize the danger, especially for children, of contact with anyone with a cold. The older children of a family often contract whooping cough at school, and then communicate it to the baby at home. The older ones recover; the baby is more liable to die. This is a common sequence and one of the chief causes of fatalities.

Wound Infection and Tetanus.

Any break in the skin may become contaminated with pathogenic bacteria and hence infected. A large wound is not essential for the introduction of organisms; a pin prick suffices. It is the type of organism introduced rather than the size of the wound which determines the result of the infection; staphylococci of low virulence may lead to a local infection with pus in the wound, while virulent streptococci may cause little or no local effect but spread into the body, causing blood poisoning. To assist in preventing infection, antiseptics are applied to wounds as soon after the injury as possible. A good antiseptic is one which kills bacteria but does not seriously injure the tissues about the wound. Iodine and similar strongly corrosive substances possess high antiseptic powers, but they are also painful and destructive; the injury from the antiseptic may be greater than from the original wound. For shallow wounds, such as abrasions, washing with soap and water removes most of the infective agents and is comparatively painless. During the World War sodium hypochlorite, called Dakin's solution, was extensively used in the treatment of large

wounds; hypochlorite is an effective and non-poisonous antiseptic safe for home use.

For wounds that are large or deep (particularly puncture wounds), lacerated or crushed, antiseptics alone are not adequate treatment. In such wounds there is danger from infection by the tetanus bacillus. This organism is a common inhabitant of the intestines of horses; it reaches the ground in manure. The bacilli develop spores and in this form may persist for years in the soil. The spores introduced into a wound are resistant to antiseptics; they develop into bacilli which multiply in the wound. The local effects are harmless, but the bacilli form a toxin which acts upon the nervous system. The first symptoms of tetanus are usually stiffness and tightness of the muscles of the jaw; this is followed by spasms of the face and neck and subsequently of other muscles until severe convulsions develop. The disease is frequently fatal. The prevention of tetanus consists in the administration of tetanus antitoxin serum, a procedure which should be carried out for all wounds that are more severe than abrasions.

The tetanus bacillus does not develop in the air but only in an atmosphere partially depleted of oxygen. Wounds that close over, that are covered with scabs, or that contain dead tissue, and especially puncture wounds, as from stepping on a nail, rake, or piece of glass, are particularly suited to the development of the tetanus bacillus. It is not the rust of a nail, as is sometimes supposed, that is dangerous; the rust indicates a nail that may have been on the ground, and tetanus bacilli occur most commonly in the soil. This is one disease in which infection literally comes from "dirt" carried into the wound.

The Venereal Diseases.

Syphilis, gonorrhea and chancroid are called the venereal diseases because in the majority of cases they are spread by the contact of venery. They are probably the most prevalent of all the contagious diseases of serious nature; they constituted one of the greatest causes of disability in the army during the World War. These diseases are preventable; but the steps necessary for their eradication are made very difficult by the moral attitude toward them assumed by many otherwise intelligent people. When this attitude is overcome, some difficulty will still remain because the venereal diseases are conveyed by direct contact. It is easier to control diseases which are transmitted by an intermediary host, as is malaria, or which are transmitted largely through contamination of food and water, as is typhoid fever.

The surroundings under which man lives can to some extent be regulated, but a man's own actions are not so easily controlled.

Syphilitic Infection.

Syphilis is an infection caused by the Treponema palladium or, as it is sometimes called, the Spirocheta pallida. It was discovered in 1905 by Schaudinn of the University of Berlin. The organism resembles a slender thread bent into the shape of a corkscrew. A powerful microscope with special dark-stage illumination is necessary to see it for, unlike most bacteria, it does not readily absorb stains.

The organism invades the body through the surface; it enters minute wounds in the skin and can apparently penetrate unbroken mucous membrane and the modified skin that covers the glans of the penis. After two or three weeks a chancre forms at the point of entry of the organisms. The chancre is a small hard elevation in the skin or mucous membrane, with its top cratered by an ulcer. This chancre marks the primary stage of syphilis. It persists for about three weeks.

The second stage follows in six to twelve weeks. It results from the spread of the parasites from the chancre and their dissemination throughout the body. The effects produced are variable; the lymph glands swell, there may be eruptions on the skin and mucous membranes of the mouth and nose; there may or may not be fever. As a rule, neither the primary nor the secondary stage causes sufficient illness to keep a man from his work. The skin eruption, which is one of the features of the secondary stage, does not show any definite characteristics by which syphilis can be certainly recognized; it may resemble the eruptions which occur in other diseases of the skin. The eruption on the mucous membranes, so-called mucous patches, appear as raw areas.

The organisms are present in the chancre of the primary stage and in the mucous patches of the secondary stage. Infection of another person may result from contact with either of these areas. The infection from mucous patches may be transmitted in kissing; the author saw a case in which a young girl, burned on the cheek by the cigarette of her companion, developed a chancre in the burn after he had "kissed it to make it well." The transmission may be—although it rarely is—effected from articles of common contact as in the use of spoons, glasses, pipes, etc., which have been recently in the mouth of a syphilitic. The organisms are present in the blood and may be transmitted through the use of razors and unclean dental instruments.

The organism causing syphilis is frail, but it may live for an hour on a moist surface.

The secondary stage of syphilis gradually subsides even without treatment. The disease may then seem to have disappeared; but unless proper treatment has been applied, the organisms are still engaged in their destructive work in the body. The evidence of this destruction may not appear for many years after the primary and secondary stages. This third stage of syphilis results in the formation of growths, each called a gumma, which may occur in any organ or tissue of the body, or in the slow inflammation of tissues as of the walls of the arteries or the brain. Disturbance of functions results, corresponding to the organs affected. A common location for the syphilitic changes is in the arch of the aorta; aneurism follows. These changes may extend to other arteries with consequences similar to those of arteriosclerosis (see pages 153 and 154). The stomach, kidneys, liver, pancreas, or other organs may be the seat of a gumma. If a gumma forms in or near the skin an open sore results; if in the nasal passage the septum of the nose may be destroyed and the bridge of the nose depressed. Syphilis may also invade the nervous system, causing locomotor ataxia and paresis (see page 353).

There is no natural immunity from syphilis; everyone is susceptible, but the severity of individual cases varies greatly. One attack of syphilis does not confer definite immunity from a second; a primary sore will not develop so long as the organisms remain in the body, but when they have been eradicated by treatment reinfection may occur.

Syphilis and Length of Life.

Untreated syphilis shortens life because of the changes occurring in the third stage. Syphilis kills slowly, and the immediate cause of death depends upon the organ in which the destructive changes have occurred; death may result directly from such conditions as apoplexy or chronic nephritis. The shortening of life by untreated syphilis is indicated by the fact that most life insurance companies refuse to accept syphilitics. Syphilis is one of the chief causes of death in early adult life in persons who appear healthy. Fortunately these drastic consequences of the disease are prevented by early and thorough treatment.

The extent to which syphilis is prevalent is uncertain; estimates

made from various sources indicate that between 5 and 20 per cent of the population have or have had the disease.

Congenital Syphilis.

Syphilis is not hereditary in the sense that it is transmitted in the germ cell; but it may be acquired by the fetus in the uterus prior to birth. The infection occurs only when the mother has the disease; the organisms in her blood pass through the placenta and into the blood of the child. In most cases of infection of this kind, the fetus dies during pregnancy or the child is born dead. Some children survive and exhibit the symptoms of syphilis; they do not develop normally and they may be crippled or even insane. However, they may be treated and cured.

Treatment of Syphilis.

Syphilis was first definitely recognized early in the sixteenth century and even at that early date mercury was used as a treatment. This metal tends to check the disease; it hastens the disappearance of the secondary stage, but alone it rarely effects a cure, for the organisms are left in the body and the third stage develops later. In the twentieth century an effective cure for syphilis was discovered by Ehrlich in Germany. He developed an organic arsenical compound known as 606, salvarsan, or arsphenamine. This drug, which is injected into the blood kills the organisms. The earlier in the course of the disease the treatment is given, the more satisfactory are the results, for damage to internal structures caused by the disease cannot be repaired.

The Wassermann test (and other similar ones) for syphilis has greatly assisted the treatment, for without this measure it is often difficult to diagnose syphilis correctly, or to tell when it is cured. The test is made on the serum of blood drawn from the patient; in many hospital wards a Wassermann test is made on all patients, whether or not they show any indication of having syphilis; in some states proof of a negative Wassermann test is required before a marriage license is issued.

Prophylaxis of Syphilis.

The site of infection in syphilis resulting from sexual contact is usually on the glans of the penis or under the surface of the prepuce, and not, as in gonorrhea, in the urethral passage. The measures used

to prevent gonorrhea will not prevent syphilis. Prophylaxis against syphilis is accomplished by applying over the entire penis and surrounding regions, within one or two hours after the exposure, an ointment containing 33 per cent of calomel.

Gonorrheal Infection.

Gonorrhea is a very ancient disease, but the organism causing it, the gonococcus, was not discovered until 1879 by Neisser. The gonococcus can enter only through mucous membrane; its point of entry in the male is usually the urethral canal and in the female the wall of the vagina or the cervix. Gonorrheal infection of the eyes is discussed in Chapter XV as the common cause of ophthalmia of the newborn.

Gonococci placed on mucous membrane do not remain on the surface but penetrate to the connective tissue beneath the mucous membrane. There they multiply rapidly, setting up an acute inflammation. Pus is formed. The mucous membrane is eroded in spots. The pus then flows from the surface, carrying with it many of the gonococci. These effects appear within two to six days after infection, usually within three to five.

Gonorrhea in Men.

In men the inflammation of the urethra causes severe pain at the time of urination; in women the effects are frequently unobserved. The course of the disease and the complications which may result from the inflammation also vary in the two sexes because of the differences in anatomical structure. In the male, the gonococci and the inflammation spread up the urethra. In favorable cases the disease involves only the lower part of the urethra. The infection may, however, pass to the upper urethra and extend into the ducts leading to the prostate gland, the seminal vesicles and vas deferens; in occasional cases it may pass into the bladder or even up to the kidneys. The extension into the vas deferens results in inflammation of the epididymis; and if both sides are affected, sterility may result when the disease heals, from the tubes being shut off by the formation of scars.

Under proper treatment gonorrhea in the male can be cured. To do so requires the highest medical skill. Too often the man who is infected regards the disease lightly and is careless in his choice of a physician. Poor treatment results merely in arresting the acute stages of the inflammation, but leaves a chronic infection. The man is then still capable of transmitting the disease; the foci of infection may

become active at any time and reestablish acute inflammation. It cannot be emphasized too strongly that the outcome of gonorrheal infection depends upon the medical skill exercised in the treatment.

Gonorrhea in Women.

In the female the gonorrheal infection started in the vagina may progress into the mucous membrane of the uterus. When centered there it usually gives rise to no noticeable effects. It may spread farther and pass into the Fallopian tubes and through them to the peritoneum lining the abdominal cavity. The inflammation of the tubes often causes them to be closed by the formation of scars; sterility results. If both ends of a tube are closed, pus cannot drain from the tube. It becomes distended from the collection, forming what is known as a "pus tube." Pain in the abdomen, high fever, and other signs of infection result. It is necessary to remove the infected tube by surgical operation. Gonorrhea is difficult to treat in women and frequently runs a prolonged course.

Gonorrheal Rheumatism.

Although gonorrhea is primarily a local disease, the gonococci occasionally spread into the blood. The infection is then carried to the joints; a very severe form of inflammatory rheumatism results. In these cases the infection may also involve the heart, causing endocarditis. (See page 176.)

Prophylaxis of Gonorrhea.

Prophylaxis against gonorrhea is largely limited to the male; it consists in washing out the urethral canal with a non-irritating antiseptic as soon after exposure as possible. Frequently an antiseptic is combined with the ointment used for the prophylaxis of syphilis; a small amount of this ointment is squeezed into the urethra.

Chancroid.

Chancroid, or soft chancre, is an ulcer which occurs on mucous membrane or skin as the result of infection by the bacillus of Ducrey. The ulcers erode the tissues and are painful. The disease, which is usually transmitted by sexual contact, develops within a day or two after infection. It is prevented by ordinary cleanliness, washing with soap and water.

Attitude Toward the Venereal Diseases and Sex.

The space devoted here to the venereal diseases is short in relation to their importance. They constitute a subject that stands apart. They have too long been viewed from a theologicomoralistic standpoint. So long as action was founded on that standpoint nothing was achieved to decrease the ravages of the venereal diseases, either upon those who were regarded as "sinners deserving punishment" or upon the vast number of those pure wives and innocent newborn children who were thus "punished for the sins of others." Only as the matter has come to be viewed as a public health problem, and one to be treated apart from moral implications, like any other public health question, has real progress been made. The treatment of sex functions and reproduction in this book has therefore been kept apart from mention of venereal diseases. The mind of every normal young man or woman is inspired by a natural and proper interest in those functions which underlie the noblest and most beautiful of human relations, marriage and parenthood.

The educated class in America has an extremely low birth rate; it is almost a dying class. It includes an abnormal proportion of the unmarried and childless, who suffer from the stunting of character which the lack of family so often involves. Particularly for such a group the conception of normal sex relations should not be perverted by the complication, so often conveyed, that sexual functions are merely the initiation of disease.

APPENDIX

THE PRINCIPLES OF MEDICAL TERMINOLOGY

MEDICAL TERMINOLOGY IS RAPIDLY BECOMING A PART OF GENERAL SPEECH. Words which only a few years ago were used exclusively by the physician now appear in newspapers, magazines and books intended for the laity. Most medical terms are not difficult to comprehend; the majority are composed of certain base words, or combining forms derived from the Greek or Latin which are used in combination with a small number of significant prefixes and suffixes. The first step toward acquiring a medical vocabulary is to learn these important and continually recurring prefixes and suffixes.

To illustrate: the suffix *itis* signifies inflammation; when attached to the term for any structure of the body inflammation of the structure is indicated. Thus appendic*itis* signifies inflammation of the appendix. Correspondingly the terms rhin*itis*, pharyng*itis*, tonsill*itis*, laryng*itis*, trache*itis*, and bronch*itis* signify respectively inflammation of the nose, throat, tonsils, larynx, trachea and bronchial tubes. As exceptions to this simple rule, the word pneumonia is commonly used for inflammation of the lungs, although the term pneumon*itis* is entirely correct. The more common medical prefixes and suffixes are listed here with their meanings.

PREFIXES

a-, an-, *without* or *absence*—also *separation from*; as *a*trophy and *an*aesthesia.
ab-, *from;* as *ab*normal.
anti-, *against;* as *anti*septic.
bio-, *life;* as *bio*logy.
dis-, dys-, *ill* or *difficult*; as *dis*ease, *dys*pepsia.
endo-, *inside;* as *endo*cardium.
hem-, *blood;* as *hem*orrhage.
hyper-, *above* or *excessive*; as *hyper*trophy.
macro-, *large;* as *macro*cyte.
micro-, *small; as micro*be.

pan-, *all;* as *pan*demic.
peri-, *around;* as *peri*cardium.

Suffixes

-algia, *pain;* as neur*algia.*
-cide, *kill;* as bacter*icide.*
-ectomy, *cut out* or *off*; as append*ectomy.*
-itis, *inflammation;* as appendic*itis.*
-oma, *tumor* or *swelling*; as hemat*oma.*
-osis, *state* or *condition* (usually abnormal); as tubercul*osis.*
-rhea, -rrhea, *flow* or *discharge*; as diar*rhea.*
-tomy, *cut;* as litho*tomy.*

The prefixes and suffixes may be applied to nouns (as *appendix* + *itis*, *appendicitis*), or to so-called combining forms (as *card* + *itis*, *carditis*).

Some Common Combining Forms

adeno, aden, *gland;* as *adeno*ma.
arthro, arthr, *joint;* as *arthr*itis.
bacterio, *bacterium;* as *bacterio*logy.
cardio, card, *heart;* as *card*itis.
costo, *rib;* as inter*costal.*
cyto or cyt, *cell;* as leuco*cyte.*
denti, *tooth;* as *dent*ology.
derm, *skin;* as *derm*atology.
entero, *intestines;* as *enter*itis.
gastro, gastr, *stomach;* as *gastro*tomy.
glosso, *tongue*; as *gloss*itis.
hepato, hepat, *liver;* as *hepat*itis.
hystero, hyster, *uterus;* *hyster*ectomy.
leuco, *white;* as *leuc*orrhea.
litho, *stone;* as *litho*tomy.
logy, *doctrine* or *science*; as bio*logy.*
nephro, *kidney;* as *nephr*itis.
neuro, neur, *nerve;* as *neur*algia.
ophthalmo, *eye;* as *ophthalmo*logy.
osteo, *bone;* as *oste*itis.
oto, *ear;* as *ot*itis.
path, *disease* or *suffering*; as *path*ology.
pharyngo, *throat;* as *pharyng*itis.

phlebo, *vein;* as *phleb*itis.
psycho, *mind;* as *psycho*logy.
rhini, *nose;* as oto*rhino*laryngology.
rrhagia, rrhage, *excessive flow;* as hemo*rrhage.*
thoraco, *chest;* as *thorac*algia.
tropho, trophic, *growth;* as a*trophy.*

The combinations that can be made from the 20 prefixes and suffixes and the 29 combining forms given here constitute a fairly extensive vocabulary of medical terms. Thus a single combining form, card, used with the suitable prefixes and suffixes, gives 12 common terms: *acardia* (without a heart); *cardiology* (study of the heart); *cardiac* (of the heart); *myocardium* (muscle of the heart); *endocardium* (lining of the heart); *pericardium* (sac surrounding the heart); *cardalgia* (pain in the heart); *carditis, myocarditis, endocarditis, pericarditis,* and *pancarditis* (the inflammations of the heart). From such combinations as these, such terms as *acute bacterial endocarditis* or *myocardial degeneration* take on definite significance. To the 12 common *card* terms given here may be added the rare ones of *cardectomy* and *cardotomy.*

In some instances a medical term may have several components, but usually there is no difficulty in breaking the word into its significant parts. Thus agranulocytosis becomes *a* (absence of) *granulo* (granules) *cyt* (cell) *osis* (condition of): condition in which there is an absence of granulated white cells.

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